SCHOOL ZOÖLOGY

BURNET

ZOÖLOGY

FOR

HIGH SCHOOLS AND ACADEMIES

BY

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BURNET ZOÖL.

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PREFACE.

At the present day, natural science is finding a place in the most elementary courses of study; and nothing is wiser or more natural than this, since it is in childhood that interest is most readily aroused and the observing faculties most easily trained. But the teacher of biology in a crowded graded school has many difficulties with which to contend. Every one will admit that he who knows a few things well is better equipped for any field of work than he who has a superficial knowledge of many things; and nowhere is this more true than in any department of natural science. The zoölogist who has thoroughly studied a few typical forms has a basis on which to build, which no amount of more general but less definite knowledge can give him. Our colleges with well-appointed laboratories afford every facility for thorough investigation, in dissection, and in microscopic and other independent work; but in schools where classes are large and time limited, and where no laboratory is provided, such work is practically impossible. After several years of experience in teaching zoölogy in the lowest grade of a high school, the author has become convinced that a text-book in which a few typical forms are clearly yet simply described should be used for class work, and this supplemented by outside individual work on the part of the pupil.

In this elementary zoölogy, comparatively few forms are described, and only such technical terms are used as are necessary, and these are defined. General characteristics and classifications are put at the end of each branch, class, or order, — a much more natural place than the usual one at the beginning of the division.

Throughout the work a great many notes are introduced which may be used at the discretion of the teacher, so that the course may be longer or shorter, as desired.

Pupils should be encouraged to observe living animals, to study their habits, to collect such specimens as can be preserved or dissected. It is in field work especially that the enthusiasm of the young pupil may be stimulated, and observation cultivated; and if he is required to report the results of his expeditions, and helped to identify and classify his collections, it is surprising how much may be accomplished in one short term. And when this pupil enters the college laboratory, he will be ready to take up the work there with greater zeal, intelligence, and skill, for the preliminary training the lower school has thus given him.

It is taken for granted in this course that the pupil has already studied at least the elements of human anatomy and physiology.

No attempt is made to furnish complete tables of classification of the animal kingdom, but at the end of each division the forms described are so grouped as to show their relationship to each other.

The author is indebted to a number of friends for assistance in preparing this work, especially to Professor George W. Harper of the Cincinnati high schools, and Dr. J. A. Lintner, entomologist of the State of New York.

CONTENTS.

INTRODUCTION.

BIOLOGY, or the science of life, is divided into two departments,—*botany*, which treats of plant life; and *zoölogy*, which treats of the life of animals.

In the study of human anatomy, we learn that our bodies are made up of millions of small elements called *cells*, and of intercellular materials produced by them; and that the life of the body is in the cells. This is not only true of our own bodies, but also of those of all animals, no matter how complex or how simple.

A cell is a small particle of albuminous matter called *protoplasm*, and contains a central point called a *nucleus*, and usually an outer, delicate, bounding *membrane*.

Animals may be one- or many-celled, but every animal comes from one original germ cell or ovum. In the many-celled animals this divides and subdivides to form at first a mass of simple generalized cells. As division goes on, however, these cells are modified in various respects, and become specialized, in order that they may form different tissues and perform different functions.

The study of the structure of the bodies of animals is called *anatomy*, and that in which careful comparisons are made between corresponding parts of different animals is called *comparative anatomy*.

The study of the development of animals from their germ cells is called *embryology*.

After a study of comparative anatomy and embryology, zoölogists have arranged or classified animals into groups according to their resemblances and relationships; but, as the constant additions to our knowledge throw new light on those relationships, classifications (which are at best but arbitrary arrangements) are subject to continual changes and modifications.

The study of animals themselves is therefore much more valuable, not only for the above reason, but because of the cultivation it gives to our powers of observation, and of the sympathy with living things aroused by it.

All the animals of any region taken together constitute its *fauna*, and the fauna of any region will furnish material for the study of almost every type of animal life.

In a general way every one knows that he must have a constant supply of food and oxygen to support life, and that what is true of man is also true of all animals, no matter how low they may be in the scale of life; but some understanding of the reasons for this are necessary to a better appreciation of the structure and life of the various animals which interest us.

All living matter, whether plant or animal, is constantly undergoing change. Protoplasm is a very complex substance, which is also very unstable; that is, it is very easily separated into less complex substances, if any disturbing substance is introduced. Oxygen is just such a substance; and when it comes in contact with the tissues of any living organism, it causes a breaking-up of these tissues into simpler substances, — carbon dioxide, ammo-

nia, etc., — which, being no longer of value to the body, are known as waste materials. The beneficial result of this change is the production of energy or *force*. All that energy which is the manifestation of animal life is accompanied by the decomposition of animal tissues: the greater the energy displayed, the greater the accompanying waste. But since this is true, if there were not some means of rebuilding the tissue so destroyed, death would inevitably result. It is for the repair of waste, as well as to supply material for growth, that food is required; and it must be of such a character, and so supplied to the cells, that it may be absorbed by them to form new protoplasm.

The process by means of which food is prepared for the use of the cell is called *digestion*. This, in the lower forms, is carried on with very little or no special apparatus, the food being acted upon and liquefied by some digestive fluid in the main cavity of the body; but in the higher animals a set of organs is found, called the *digestive apparatus*. This consists of mouth, stomach, intestines, liver, etc. Its function is to reduce the food to a condition in which it can be used by the cell.

After the food is prepared for use, it must be taken by the cell. The process by means of which the cell appropriates and makes use of the nourishment furnished it, is called *assimilation*.

In most animals it is necessary that some means be provided for conveying this digested food to the cells. The process by which this is done is called *circulation*. It is accomplished in the higher animals through an intricate system of organs; namely, a heart, which acts as a pump to force the circulating fluid about the body, and arteries,

veins, and capillaries, — tubes in which it may flow. But, as in the case of the digestive process, this is not true in the lower and simpler forms, where the nutrient fluid may merely circulate in the spaces of the body. The circulating fluid of the higher animals is blood; but in the lower, it is simply water in which food and oxygen are dissolved.

Oxygen is brought into the body by the process of *respiration* or *breathing*. In the lower forms it is absorbed from air particles in the water which directly bathes the tissues. But this function is, in the higher animals, generally performed by lungs when the oxygen is taken from the atmosphere, or by gills when it is taken from air particles found in water. These organs furnish oxygen to the circulating fluid of the body, and by means of this it is carried to the cells.

One other process is necessary to the health of the animal; namely, *excretion*, or the removal of waste material from the body. This is performed, partly by the act of breathing (waste materials being exhaled), partly by means of special organs.

An animal can live only so long as these processes of digestion, circulation, respiration, assimilation, oxidation, and excretion go on; and when any one ceases, death must result.

In animals of complex organism, it is necessary that the various vital processes be controlled and harmonized. This is done by means of a *nervous system*, consisting, in man, of a brain, spinal cord, and other ganglia or nerve centers, together with nerves which connect these centers with the parts to be regulated. And this system controls not only the vital processes of the body, but also its

voluntary activities; and, moreover, it brings the animal into relationship with the outside world through consciousness of its surroundings. Impressions received from without are called *sensations*, and these vary in number and amount according to the development of the nervous system. In many low forms the sensitiveness of the animal is comparatively slight, and, no special nervous tissue being present, the function of sensation is merely exercised independently by each cell of the body.

BRANCH I. — PROTOZOA.

Amœba. — The simplest form of animal life is the *amœba.* This little animal is usually microscopic in size, living in the ooze at the bottom of ponds and aquaria or in sediment on water plants. It consists of a single cell, with an outer jelly-like portion (*ectosarc*) surrounding an inner granular and more fluid portion (*endosarc*). In the interior is a distinct *nucleus* and a pulsating *vesicle* or *vacuole.* The nucleus consists of a clear and more solid particle in the granular interior. The vesicle appears in the ectosarc as a point, increases to a certain size, and then disappears, to reappear in the same manner at the same place, the pulsations occurring at regular intervals. It is uncertain whether the vacuole is an opening in the outer covering to admit water, or a cavity formed within the body of the amœba; but it seems to cause a movement or circulation of the granular interior, and possibly corresponds to the heart of the higher animals.

If the amœba be watched under the microscope,[1] it will

[1] Material for microscopic work may easily be obtained. Pond scum, stagnant water from gutters and ditches, water in which plants have been slipped or cut flowers been kept till they have wilted, sediment on plants in aquaria, all contain, beside the low plant forms, many one-celled animals. A quarter-inch objective is usually strong enough to show the nucleus and contractile vesicle. A higher power is sometimes needed to bring out the cilia.

be observed that slowly the outer clear portion begins to bulge at some point, and extend out from the body of the

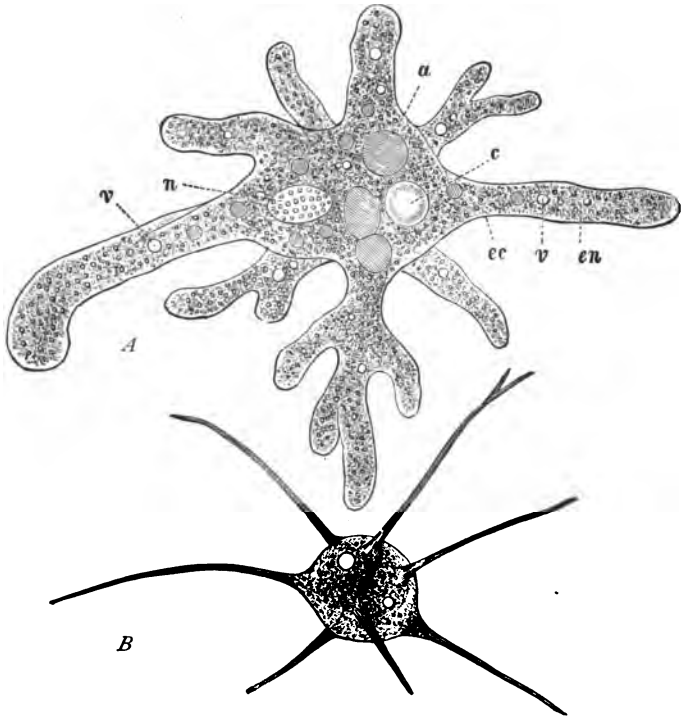

FIG. 1. — *A*, *Amœba proteus*, with the pseudopodia protruded, enlarged 200 diameters (after Leidy): *n*, nucleus; *c*, contractile vesicle; *v*, one of the larger food vacuoles; *en*, the granular endosarc; *ec*, the transparent ectosarc; *a*, a cell of an Alga taken in as food (other cells of the same Alga are obliquely shaded). *B*, *Amœba radiosa*, enlarged 500 diameters (after Leidy). The body shows two large vacuoles, but no nucleus or contractile vesicle. The long and delicate pseudopodia are protruded.

animal; and that gradually the fluid interior and the rest of the body is drawn after this; and that by this movement the amœba slowly progresses along surfaces. The

bulging portion is called a *pseudopodium.* Sometimes instead of one there are several pseudopodia, giving the amœba a very irregular shape. Of course, this change of form could never occur if the amœba were protected by any membrane; nor could it ingulf its food as it does, if any such membrane were present.

The amœba feeds principally on microscopic plants, about which its body flows, two pseudopodia meeting about the food particle and inclosing it, so that it is contained in the fluid interior. Here it is slowly dissolved by some digestive agent, and the slow circulation of the granular interior brings the digested food to every portion of the body.

The amœba absorbs oxygen from air dissolved in the water, and throws off carbon dioxide, this corresponding to the respiration of higher animals.

The reproduction of the amœba is by simple division, similar to the division of cells in higher organisms, the two parts separating to become distinct individuals.

Under certain unfavorable circumstances, the amœba and other protozoans surround themselves with a tough outer membrane, or *cyst*, and remain quiescent for an indefinite period.

FIG. 2.—MONAD (greatly enlarged): *F*, flagellum; *Pv*, pulsating vacuole; *N*, nucleus.

Monad. — Another one-celled animal also found in more or less stagnant water is the *monad.* This animal differs from the amœba in several respects. It is pear-shaped in form; and, although it can elongate or contract its body a certain amount, its

form is much more constant, owing to the fact that it has a distinct membranous covering.

To the narrow end of the body is attached a lash or flagellum whose vibrations propel the monad rapidly through the water. This flagellum is also used to lasso food particles and thrust them into the mouth, which is an opening at its base. The reproduction is by simple division.

Paramecium. — Like the monad, this animal differs from the amœba in having an outer membrane and a distinct

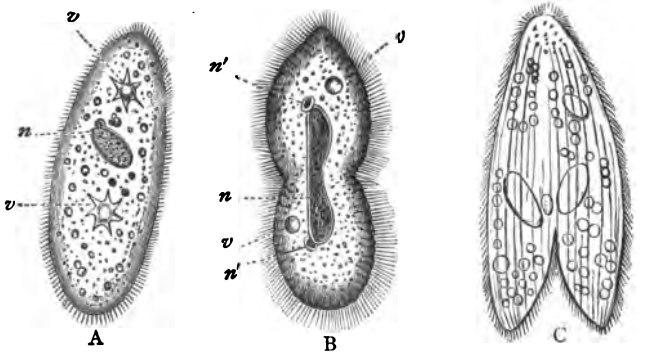

FIG. 3. — CILIATED INFUSORIA.

A, *Paramecium*, showing the nucleus (*n*) and two contractile vesicles (*v*).

B, *Paramecium bursaria* (after Stein), dividing transversely: *n*, nucleus; *n'*, nucleolus; *v*, contractile vesicle.

C, *Paramecium aurelia* (after Ehrenberg), undergoing "conjugation," two individuals being partially united by their ventral faces.

mouth opening. It differs from the monad in its locomotion. Instead of a single lash, the paramecium is provided with many cilia, whose movements propel it about.

Vorticella, or Bell Animalcule. — This one-celled animal is found attached to plants or other objects immersed in water. The body is bell-shaped (with the small end down), and is attached to its support by a slender stalk.

Above the opening of the bell is a flat disk-like cover. Both the edge of the bell and that of the disk are ciliated. Between these edges is a groove which at one point deepens and opens downward to form the mouth.

When undisturbed, the stalk upon which the bell rests is stretched out and perfectly straight, the mouth open, the cilia actively vibrating; but at the slightest shock, the disk is withdrawn, and the edges of the bell curl in and give the body a globular form, the cilia having disappeared. At the same time, the stalk is drawn into a close spiral, moving the animal nearer its support.

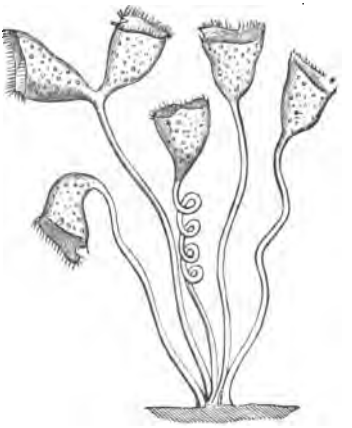

FIG. 4. — GROUP OF VORTICELLÆ.

The vorticella obtains its food by the vibration of the cilia creating currents in the water, in this way bringing food particles within reach of the mouth.

The usual mode of reproduction is by division.

General Characteristics. — It will be seen from these typical forms, that protozoans, while differing in some respects, have important characteristics in common; that they consist of single cells, usually nucleated, each with an inner digestive cavity, and generally with a pulsating vacuole; that they are generally microscopic in size, and found in stagnant water; that they reproduce by division.

Note. — Sometimes a protozoan will reproduce by becoming encysted, and dividing into a number of spores, which finally, in

an active form, escape from the cyst, each becoming a new individual.

Suggestions for Review. — Compare the vorticella with the amœba, with the monad, and with the paramecium, showing in each case the resemblances and differences. Show that the points of resemblance common to all constitute the general characteristics of the branch. Compare a monad with a ciliated epithelial cell in the lining of the human lungs. The former exercises all the functions of life; the latter has a special function to perform as a part of a highly organized body, and receives its food prepared for assimilation.

CLASSIFICATION.

(*Branch.*)	(*Class.*)	(*Order.*)	(*Examples.*)
Protozoa	Rhizopoda	Foraminifera . . .	Amœba.
	Infusoria	Flagellata	Monad.
		Ciliata	Paramecium and vorticella.

Books for Reference.

Martin and Huxley's Practical Biology.
Needham's Elementary Lessons in Zoölogy.
Kent's Infusoria.
Kingsley's Standard Natural History.
Davis's Text-Book of Biology.

BRANCH II. — PORIFERA.

The Sponge. — Probably the lowest form among the *Metazoans*, or many-celled animals, is that of the *sponge*. The ordinary sponge of commerce, such as the bath sponge, is the skeleton of an animal that lives on sea bottoms attached to rocks or other solid objects by means of a sucker-like base. The name *Porifera* is well applied to the branch, as the whole body of the animal is penetrated in every direction by pores or channels through which the water circulates. These pores are of three general classes. The largest are few in number, are nearly vertical, and never extend quite to the base. The second in size extend from the exterior, and connect with the large ones. The smallest run across in every direction, connecting the others.

The sponge has an outer membrane (*ectoderm*) covering it, except at the opening of the pores, and resembling wet kid. The pores are lined with another membrane (*endoderm*). Between these, and containing the fibrous skeleton, is a soft mass of cells, the flesh of the sponge (*mesoderm*).

The elastic fibrous skeleton is of a horny substance, and is secreted by the cells of the mesoderm. The water enters through minute holes in the ectoderm, and, circulating through the smaller channels, is finally expelled through

the large pores. This circulation is kept up by certain peculiar cells of the endoderm. In enlargements of the secondary channels, or in sacs connecting with them, are cells which, from their resemblance to monads, have by some been considered as distinct individuals, and the sponge thus a colony of animals. These cells are packed side by side; the inner end of each (that towards the center of the channel) bearing a peculiar collar-like arrangement, from the opening of which projects a cilium or lash. The constant vibration of these cilia creates a current in the water, which keeps it moving through the pores. In the water so drawn into the sponge are many minute plants and animals which these ciliated cells lasso after the manner of the monad. Each cell digests in its interior what food it takes, and, besides nourishing itself, supplies digested food to other parts near it. The sponge also absorbs oxygen through its endodermal cells.

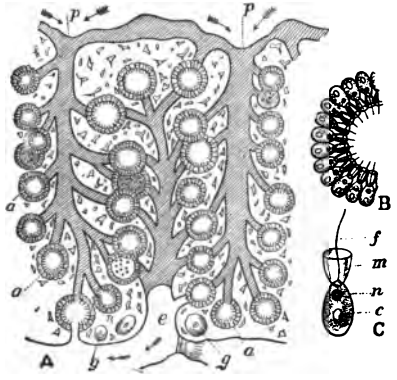

FIG. 5.—STRUCTURE OF SPONGIDA.

A, Vertical section of the outer layer of *Halisarca lobularis*, a sponge in which the skeleton is wanting: *pp*, pores or openings of inhalant canals, by which water is conducted to the ciliated chambers (*aa*); *e*, commencement of a larger exhalant canal; *gg*, young stages of the reproductive bodies or spores.

B, Part of a single ciliated chamber of same sponge, transversely divided, showing flagellate cells or sponge particles, with their inwardly directed flagella.

C, A single flagellate cell of the same: *f*, flagellum; *m*, collar round the base of the flagellum; *n*, nucleus; *c*, contractile vesicle.

The young sponge is produced from an egg. The germ

cell forms in the mesoderm, divides and subdivides, finally forming two cell layers. Some of the surface cells become ciliated. In this condition it leaves the sponge, propelling itself by the cilia. After a time it finds a suitable resting place, puts out its sucker-like base, develops pores, skeleton, etc., and becomes a sponge like the parent form.

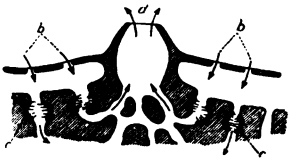

FIG. 6. — CIRCULATION OF WATER THROUGH THE SPONGE: *d*, large hole; *bb*, smaller pores; *cc*, cup-shaped hollows in canals.

There are several varieties of commercial sponges. The best are obtained in the Mediterranean; but other grades come from the Red Sea, Gulf of Mexico, Caribbean Sea, and off the Bahama Islands. They are obtained in three ways, — by diving, by dredging, and by harpooning. The best grades live in deep water, being obtained at a depth varying from thirty to forty fathoms. The absence of currents, the greater clearness and more even temperature of the water, and the greater abundance of food stuff, cause a better development; and the absence of impurities, and the greater density of the skeleton, give it greater elasticity.

FIG. 7. — LIVING SPONGE IN ACTION.

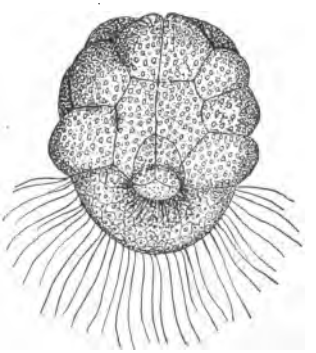

FIG. 8. — YOUNG SPONGE.

Besides the horny or commercial sponges are those whose skeletons are siliceous, and others with limy skeletons. In fresh water is found another kind. None of these are of any commercial or practical value. Those horny sponges found in colder seas are not of any commercial value, because they are too ragged and poorly developed.

Note. Method of obtaining Sponges. — The dredge used in sponge gathering is a stout netting bag with an iron frame. This is dragged along the sea bottom, cutting or tearing off sponges, which drop into it.

The harpoon is used in shallow water, and consists of a fork set on a slender pole. This is used to bring up the coarser varieties of sponges.

The best sponges are obtained by diving, and at depths varying from 90 to 240 feet. In some places diving suits are used, but generally the diver merely relies on holding his breath long enough to remain from two to three minutes beneath the water. Going out with two or three others in a boat, he divests himself of his clothing, slings a netting bag about his neck, and takes in his hands a rock to which a rope is attached, and which acts as a sinker. Then fully inflating his lungs, he plunges head first into the water. On reaching the bottom, he quickly cuts as many sponges as he can, throwing them into the sack. When he can hold his breath no longer, he jerks the rope as a signal to his companions in the boat above, and they immediately haul him up with his load. Care must be taken to cut these sponges close to their bases. Should the diver, failing to signal in time, let out his breath, the distance to the surface of the water, and the weight of the sponges he carries, leave him no chance for life. Divers are usually short-lived.

A full account of the various methods employed in gathering sponges, and in preparing their skeletons for the market, will be found in any good encyclopedia.

General Characteristics. — It will be seen that the peculiarities of the sponge[1] are its porous body, its three membranes, its ciliated endodermal cells, no digestive or respiratory organs except these cells, no nervous system. Reproduction is by eggs, though bits torn off have been known to live as individuals.

Suggestions for Review. — Compare a commercial sponge with an amœba. What essential differences exist between them? In what ways do they resemble each other? The resemblances are in such points as place them both in the animal kingdom; the differences cause them to be classed under separate branches. Compare a collared endodermal cell with a monad. Compare it with a ciliated epithelial cell from the human lungs.

Books for Reference.

Guides for Science Teaching, No. III.
Needham's Lessons in Zoölogy.
Kingsley's Standard Natural History.

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[1] To study the skeleton sponge, get a perfect wool sponge with large holes which open at the top, but not running through to the base. Test its elasticity, wet and dry. Examine its fibrous structure, and put some of the fibers under the microscope to see their structure. If alcoholic specimens of the commercial sponge can be obtained, the character of the flesh may be seen.

BRANCH III. — CŒLENTERATA.

The Hydra. — The simplest animal in this branch is the fresh-water *hydra.* It is found in ponds and streams, often attached to leaves or stems of plants. It is tubular in form, and from a quarter to a half inch in length. There are two varieties, — one red or flesh color, the other green.

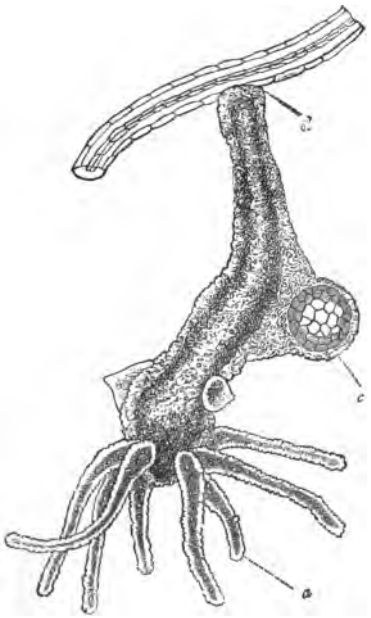

FIG. 9. — FRESH-WATER HYDRA, SUSPENDED HEAD DOWNWARDS FROM A PIECE OF A STEM OF AN AQUATIC PLANT: *a*, one of the tentacles; *c*, a single large ovum, protruding from the side of the body; *d*, disk of attachment.

The hydra consists of two membranes, — ectoderm and endoderm. The body is closed at one end, the open end or mouth being surrounded by numerous thread-like *tentacles*, often longer than the body itself. Upon the ectoderm, and especially upon the tentacles, the microscope reveals certain oval cells, in each of which a thread is

coiled that can be discharged when the cell is irritated. Each little thread is a poisoned dart, and when all the darts are used upon the body of a water flea or other tiny animal, their combined action paralyzes the victim, which is then thrust by the tentacles into the mouth of the hydra.

The stomach, which is the whole interior cavity, is supplied with a fluid by means of which digestion is accomplished; but there are no circulatory nor respiratory organs, neither can any nervous system be detected.

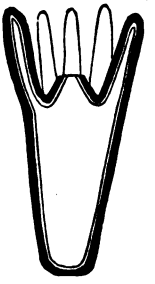

FIG. 10.—DIAGRAMMATIC SECTION OF HYDRA. The dark line is the ectoderm, the fine line and clear space adjacent indicate the endoderm.

The reproduction of the hydra is by means of eggs (as in the sponge) or by budding. The bud begins as a knob-like extension on the side of the hydra, its cavity continuous with the body cavity. As its size increases, an opening appears at the outer point, and a circle of tentacles develops around it. After this, the connection between the bud and the parent form begins to decrease, gradually narrowing until the bud is detached and becomes an independent animal. Experiments have been tried with hydras, which prove that they can reproduce by division. Sections cut from the hydra in either direction develop into perfect forms. Turned wrong side out, though the ectoderm becomes endoderm, and endoderm ectoderm, the animal thrives.

The hydra moves in several ways. It swims by means of its tentacles. It attaches itself by a sucker-like base

to solids, along which it slowly slides without lifting its sucker. But its most rapid progress is made by a series of movements like somersaults, alternately putting down tentacles and base.

Hydroids and Jellyfishes. — Closely allied to the hydra are the colonied *hydroids*, which are so varied in their characteristics and in their life histories, that it is hard to select a typical form. A colony often so resembles a plant in appearance, that it may be mistaken for a seaweed.

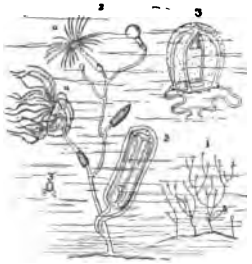

FIG. 11. — CAMPANULARIA. 1, Half natural size. 2, Animal magnified: *S*, sac containing jelly bell; *a*, animal feeding. 3, Free-swimming young, magnified. 3′, Jelly bell, half natural size.

The living parts in a colony are called *zoöns* or *zooids*. Usually the zooids are like the hydra in structure, being tubular, with mouth and tentacles, and the stomach the only cavity of the body. The zooids are connected with each other by a hollow branching stalk; and food digested by one zooid may be distributed to other members of the colony. Sometimes the zooids in a colony have each a special function; the work of food gathering, food digesting, and egg producing being performed by separate individuals. Some of these colonies secrete lime, and leave branching skeletons much like those of some corals. Some are free-swimming and have locomotive zooids (as in the Portuguese man-of-war).

Some interesting forms reproduce by alternate generation. In one species the lower buds, instead of having a hydra-like structure, are oval in shape, and from them

are born little bell-shaped *jellyfishes*. These are transparent and luminous. From the center of the inverted bell hangs a proboscis, at the outer end of which is the mouth. Four tubes run from the central cavity or stomach to a circular tube around the margin of the bell. This jellyfish is provided with tentacles, which are very long in proportion to the size of the animal. It moves by a contraction and expansion of the bell. It produces eggs, from which are born little pear-shaped bodies, that, sinking to the sea bottom, develop, by budding, into so many colonied hydroids. Thus from the buds of the colonied hydroid spring jellyfishes, from whose eggs in turn come the founders of new colonies.

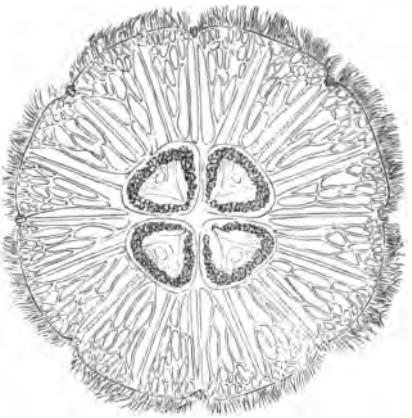

FIG. 12. — ADULT AURELIA, SHOWING THE WATER-VASCULAR CANALS.

In another species the jellies are produced by division of the hydroid. At the top of the little pear-shaped body, by a peculiar constriction, a portion of the body is partially separated from the rest as a saucer-like form. By repetitions of this process during the growth of the hydroid, it looks in time like a pile of much-scalloped saucers (Fig. 13). Then the top saucer dies and drops off; the others are completely separated, and, becoming inverted, float away, each developing into a perfect jelly.

In every jellyfish the nervous system consists of a nerve ring about the mouth, and branches from it. There are eyes on the margin of the disk. The tentacles, like those of the hydra, are armed with stings. Some jelly-

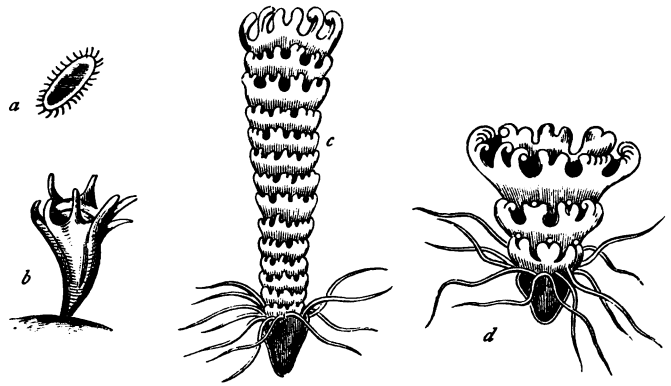

FIG. 13. — DEVELOPMENT OF AURELIA: *a*, ciliated free-swimming embryo or planula; *b*, hydra tuba; *c*, hydra tuba in which fission has considerably advanced; *d*, hydra tuba in which fission has proceeded still further, and a large number of the segments have been already detached to lead an independent existence.

fishes are produced directly from eggs. Most hydroids and jellyfishes are marine forms.

Sea Anemone. — Higher and more complex in its organism than the hydra is the *sea anemone.* This animal lives in all parts of the ocean at all depths. It is cylindrical in form, holds to some solid base by a sucker, and has its mouth, like the hydra's, at the top, and surrounded by tentacles. But, instead of being the single cavity of the body, the stomach of the anemone is surrounded by a space (which separates it from the outer wall), and extends two thirds of the way down from the top. It is held in place and united to the outer wall by six fleshy parti-

tions, consisting of double layers of membrane. These partitions completely separate the outer cavity into six divisions. Between the main septæ are intermediate ones extending from the outer wall in towards the center, but not reaching the stomach.

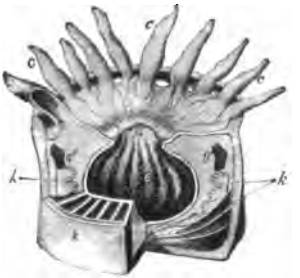

FIG. 14. — STOMACH AND CHAMBERS OF SEA ANEMONE: *c*, tentacles; *d*, mouth; *e*, stomach; *g'*, openings in the partitions; *k*, chambers.

The food, which is paralyzed by the darts on the tentacles, is dropped into the mouth. In the stomach it is completely digested, and then passes on, mixed with a large proportion of sea water, into the central space below, whence the mixture passes outward between the free edges of the septæ. Then it circulates upward, bathing all the membranes of the body; and being gradually deprived of food, and the air dissolved in it of oxygen, the water escapes through the holes at the tips of the hollow tentacles. Any hard parts do not escape from the stomach downward, but are expelled through the mouth. This circulation of sea

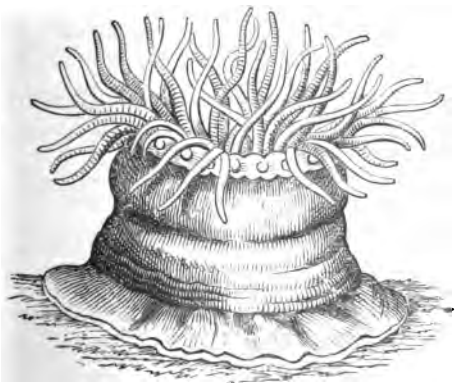

FIG. 15. — A SEA ANEMONE.

water containing digested food corresponds to the blood circulation of higher animals by furnishing the cells with their proper nourishment. It also does away with the necessity for any special organs of respiration, since the oxygen contained in the air particles dissolved in the water can be taken by the cells of the different tissues of the animal, all of which are bathed by it.

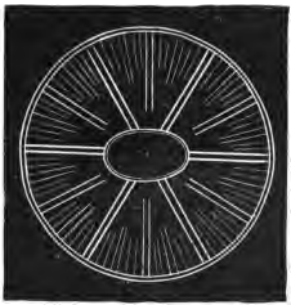

FIG. 16. — CROSS SECTION OF ANEMONE, SHOWING SEPTA.

The sea anemone has a very simple nervous system, can tell light from darkness, and has a slight sense of smell.

The anemone reproduces by eggs, which form on the septæ, become ciliated bodies, and, escaping into the ocean, develop into the parent form. The anemone also buds, the buds forming close to the base, and breaking away to become independent animals.

FIG. 17. — SEA ANEMONE AS IT APPEARS WHEN CONTRACTED.

Many anemones, especially in the warmer seas, are highly colored, and, with their fringing tentacles, are truly flower-like in appearance.

Corals. — Similar in general plan of structure is the *coral polyp*, the main difference between it and the anemone being that the coral secretes a limy skeleton. The

lime is heavy at the base of the polyp, and is secreted in its septæ two thirds of the way up. No lime could be secreted in the upper part of the body without preventing the free movements of mouth, tentacles, etc. As in the sea anemone, the septæ of corals are in multiples of six.

A few corals live as independent animals; but most of them are colonied forms produced from one single polyp by budding; the buds growing from the base in some species, upon the sides in others. The polyps in the different species vary in size. In the commonest they are not much larger than a pin head. Some corals live in northern seas, but they are most numerous and flourishing in the warmer ones. The reef-building species are as interesting to the geologist as to the zoölogist.

The formation and growth of a reef are as follows: Free-swimming young corals, similar in structure and habit to the ciliated young of the anemone, locate upon a sea bottom at a depth of not over 120 feet. This is usually close to the shore. As they will not live in water the temperature of which falls below 68°, the locality in which a reef is formed must be in or near the tropics. Each young coral becomes the founder of a colony which grows continually, the lower forms dying, but leaving their skeletons

FIG. 18.— BRANCHING CORAL ALIVE, WITH POLYPS EXPANDED.

to support the living portion of the colony. Branches interlace, and form a network. As the reef progresses, pieces of coral broken off by the waves, shells, and bones of other inhabitants of the sea, are ground up and washed into the interstices, until the reef becomes a solid mass of rock. After the reef has reached the upper limit for these deeper reef-building species, they die; but upon the surface so formed, shallow-water species locate, and carry on the work, which progresses until it has reached the level of high tide, where it must cease, since corals cannot build beyond the reach of the waves. Upon this foundation, sediment, driftwood, etc., with the decomposed substance of the reef itself, form a thin soil; seeds carried by the wind and waves, or by birds and insects, lodge and take root; and the reef is covered with vegetation, and becomes an island.

Since corals will not live in water that is fresh, muddy, or with strong currents, breaks occur in reefs opposite the mouths of streams.

Many of the islands of to-day, as well as a considerable portion of our continents, have been built by the corals. The peninsula of Florida owes its existence to them, and there are in many parts of our land rocks whose fossil forms prove them to be largely composed of the skeletons of these animals.

Besides the white corals, and related to them, though differing in several respects, are the *red* or *precious coral*, *organ-pipe coral*, *sea fans*, *sea pens*, etc.

General Characteristics. — In the *Cœlenterata* all the animals will be seen to be alike in having a central digestive organ, the principal cavity of the body; a mouth

encircled by tentacles which are armed with stings; no blood circulation, the digested food being dissolved and carried in sea water; respiration without special organs; nervous system poorly developed; reproduction both by eggs and by budding.

Suggestions for Review. — Compare the sea anemone with the hydra. Compare the branching coral with a lime-secreting hydroid. Give two points in which the hydra and sea anemone differ from the branching coral and lime-secreting hydroid. Compare the jellyfish with the sea anemone. Compare one of these typical forms, as the hydra or sea anemone, with a sponge. Why are they classed under different divisions of the animal kingdom?

CLASSIFICATION.

(*Branch.*)	(*Class.*)	(*Order.*)	(*Examples.*)
Cœlenterata	Hydrozoa	Hydroids	Hydra, hydroids.
		Discophora	Jellyfishes.
	Actinozoa	Actinaria	Sea anemone, corals.
		Alcyonaria	Red coral, sea fan, Sea pen, etc.

Books for Reference.

Guides for Science Teaching, Nos. IV., V.
Dana's Corals and Coral Islands.
Kingsley's Natural History.
Davis's Text-Book of Biology.

BRANCH IV. — ECHINODERMATA.

The Starfish. — This is generally selected as the typical form in this branch. This animal has usually a star-like,

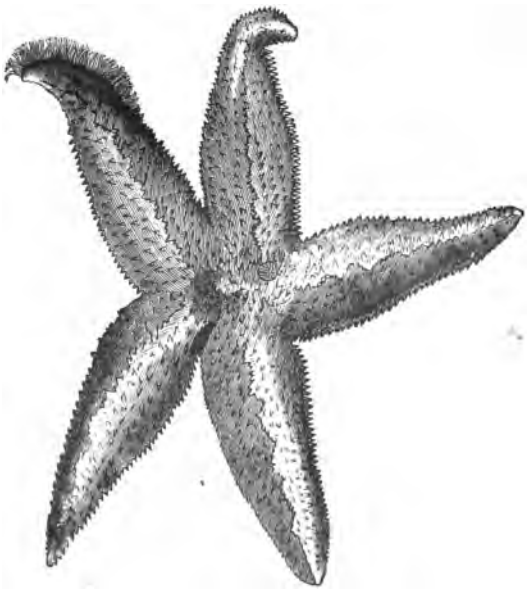

FIG. 19. — THE COMMON STARFISH, VIEWED FROM ABOVE (NATURAL SIZE).

five-pointed body, with a rough or spiny covering, a mouth in the center of the under side, and its arms or rays rather pliable.

Its skeleton consists of flat calcareous pieces or plates, varying in shape. These plates are imbedded, edge to edge, in a leathery skin, and are held together, lined, and covered by it. Between them are many pores for the admission of water to the body; and the plates grow by additions to their edges. Attached to the plates, and moving by a ball-and-socket joint, are defensive organs, — spines. The curious fact about the joint is, that, unlike most ball-and-socket joints, the socket is in the end of the movable piece (the spine), the ball on the fixed part (the plate). Among the spines on some regions of the body are some which end in movable, fork-like prongs, which act like pincers (*pedicellariæ*). The use of these is uncertain.

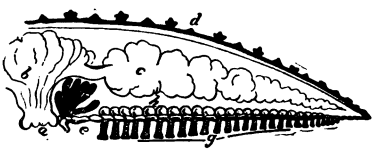

FIG. 20.— INTERIOR OF RAY: *a*, mouth; *b*, stomach; *c*, intestine; *d*, upper surface; *e*, limestone plates; *g*, tube feet; *h*, water bags.

Along the under side of each ray, running down the center, is a deep furrow; and through openings in the plates in this part extend elongated, tubular, membranous sacs or suckers. These are in four rows in each ray. The outer end of each sucker is dilated, and presents a flat surface. By extending a ray, and holding to the rocks by the suckers on it, the starfish slowly drags itself along. These suckers are therefore frequently called *feet*.

The digestive apparatus consists of the mouth on the under side, the stomach above it, in the center of the body, having a short extension connecting with an intestine in each ray. There is, also connecting with each intestine, a liver, secreting a very bitter fluid. The part of the stom-

ach near the mouth can be reversed and thrust out of the body to suck in food, the starfish subsisting on such soft-bodied animals as the oyster.

FIG. 21.— DIAGRAM OF THE AMBULACRAL SYSTEM OF ECHINUS: *m*, madreporic plate; *s*, stone canal; *r*, central esophageal ring; *a*, radiating ambulacral vessels. Only the bases of four of the radiating vessels are shown; and a few of the tube feet (*t*), with their secondary vesicles, or *ampullæ* (*v*), are shown on one side of one of the radiating canals.

There is a distinct and complicated blood circulation for the distribution of the digested food; but the water-vascular circulation, which is connected with the function of respiration, is better understood. Upon the top of the animal, in an angle between two rays, is a perforated sieve-like body, the *madreporic plate.* This admits water to a tube (the *stone canal*) which leads downward into a canal encircling the mouth. This circular canal connects with tubes running out along the furrow on the under side of each ray; and the radial vessels in turn connect with series of little sacs (*ampullæ*) in the interior, which correspond

and connect internally with the feet, and from which these feet may be filled with water. Besides acting as locomotive organs, these suckers act as organs of respiration. The heart of the starfish lies close against the stone canal.

The nervous system has its centers in a ring about the mouth; and nerves extending along the median line of the furrow under each ray supply the feet, and also a red eye spot on the tip of the ray. The eye is probably only capable of distinguishing light from darkness. The starfish has also a sense of smell.

The reproduction of the starfish is by eggs, but the stages of development are too intricate to be described here.

Besides the common starfishes are some curious forms, such as *sand stars*, *basket stars*, etc.

FIG. 22.—A FOSSIL CRINOID.

Crinoids. — Allied to the starfish is a class of animals, commonly called *sea lilies*, which is better represented in fossil than in living forms. A crinoid is attached to the sea bottom by a jointed stalk, and the disjointed pieces of these stalks are the little rings so frequently found in limestone rocks, and often called "button molds."

The crinoid itself somewhat resembles the starfish with its body inverted. The best developed crinoids have many branching, plume-like rays, which suggest a flower. In

crinoids, as in the starfishes, the parts of the animal are in fives; and this is true not only of the animal, but also of its stalk, which is often distinctly pentagonal. Some crinoids, during the later stages of existence, break away from their stalks, and become free-swimming. This accounts for the fact that frequently multitudes of the fossil stalks will be seen where the fossil form of the animal itself is not found.

FIG. 23. — A LIVING CRINOID (West Indies).

Sea Urchin. — This animal is also allied to the starfish. Its body shows the same radiate structure, the parts being in fives, though this is not so apparent externally. The sea urchin is shaped somewhat like an orange or melon, with the mouth below, and the madreporic plate near the center above. If the rays of the starfish could be bent up and over, and the ends gathered together around the madreporic plate, it would give some idea of the structure of the sea urchin. This brings the eye spots in a circle around the center of the top. The feet are in five bands of four rows each, running vertically from the eye spots on top to the

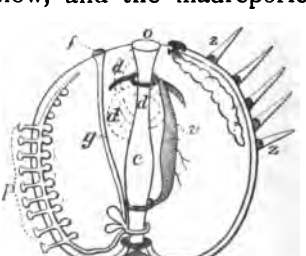

FIG. 24. — SECTION OF A SEA URCHIN: *a*, mouth; *c*, stomach; *d*, intestine; *o*, anus; *v*, heart; *f*, madreporic body; *g*, main water tube; *p*, tube feet; *z*, spines.

mouth below, and between these bands are many very long and movable spines.

The mouth of the sea urchin differs greatly from that of the starfish. The sea urchin has five sharp teeth pointing towards each other. They are movable by muscles, and grow at the root as fast as they wear off at the tip.

FIG. 25.—SHELL OF A SEA URCHIN WITHOUT SPINES.

Some curious sea urchins are known as *sand dollars*, *sand plates*, and *sea bears*. Allied to the starfish, is another form, the *sea cucumber*, which differs in several respects.

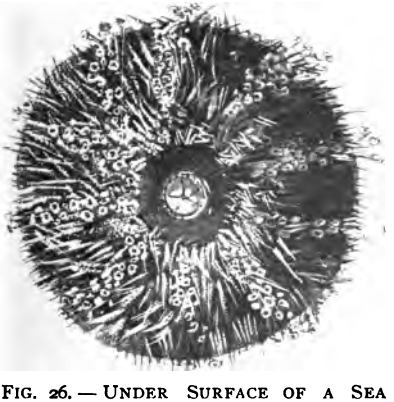

FIG. 26. — UNDER SURFACE OF A SEA URCHIN, SHOWING ROWS OF SUCKERS AMONG THE SPINES.

General Characteristics. — The echinoderms are marine animals formerly called *radiates*, because of the symmetrical arrangement of the parts around a common axis. Their principal circulation is the water-vascular one. The digestive apparatus is tubular and fairly developed, the nervous system not so well organized. The reproduction is by eggs.

Suggestions for Review. — Compare a starfish with a sea anemone; with a jellyfish. Why were all the animals of the two branches to which these three belong formerly classed together in a branch called *Radiata?*

CLASSIFICATION.

(*Branch.*)	(*Class.*)	(*Examples.*)
Echinodermata	Crinoids	Sea lilies.
	Asteroidea	Starfishes.
	Echinoidea	Sea urchins.
	Holothuroidea	Sea cucumbers.

Books for Reference.

Guides for Science Teaching, No. V.
Kingsley's Standard Natural History.

BRANCH V. — VERMES.

The Earthworm. — Of this branch the common *earthworm* is a familiar form. It is most interesting to the biologist, because, while simple in structure, it presents characteristics which continue through all the higher branches. Its body is tubular in form, and though it has no distinct head, yet it shows decidedly an anterior and a posterior region, a dorsal and a ventral region, and a bilateral symmetry (namely, corresponding right and left sides), all of which are characteristics of the higher animals, even of man himself.

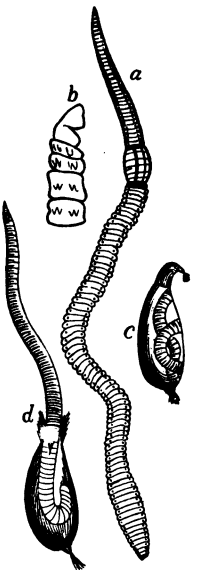

FIG. 27. — EARTHWORM: *a*, the worm itself; *b*, a small part magnified to show bristles pointing backward; *c*, egg of worm; *d*, young worm coming out of the egg.

The body of the earthworm is distinctly segmented, the segments often numbering more than two hundred; and it appears to have double the true number, owing to a wrinkle or fold of skin halfway between the divisions.

The posterior end of the body is somewhat flattened, and is not so pointed as the anterior. The first segment of the body consists of an

overhanging lip, below which is the mouth. Not very far from the anterior end is a broad white band (the *clitellum*, or saddle) upon which is secreted the capsule that envelops and protects the eggs.

Just beneath the skin are two layers of muscles, — the outermost circular, whose contractions narrow and elongate the body; the inner longitudinal, whose function it is to shorten the body. Protruding through the skin on the ventral side are four double rows of bristles, or *setæ*, which assist in locomotion. The earthworm moves partly by alternately elongating and shortening its body, partly by shoving with its setæ. It climbs smooth, vertical surfaces, aided by the slimy fluid which the skin secretes.

The digestive apparatus is somewhat tubular. The pharynx is dilated and reversible, and can be protruded from the mouth as a proboscis. Back of the sixth segment the tube narrows into an esophagus. Beyond this it enlarges to form first a crop, and then a gizzard. It is completed by a tubular intestine. Above the intestine lies a liver.

The circulation is of two kinds. Red blood circulates in a distinct system of tubes. A dorsal vessel, whose course can be traced under the skin, carries it toward the anterior region. A ventral vessel returns it in the opposite direction. In every segment, one or two vessels on each side connect the dorsal with the ventral, the corresponding right and left vessels together encircling the segment. The five vessels in the segments 7–11 inclusive, are enlarged, and pulsate by the contraction of their muscular walls. They take the place of a heart. Besides this red blood, the earthworm has colorless blood. This circulates in the cavities of the body, and is thought to carry the digested

food. Capillaries carrying red blood are distributed in the skin; and the earthworm breathes by absorbing oxygen through the skin, which is kept moist for this purpose.

A double chain of ganglia runs along the ventral side of the body; and the fibers of this divide at the esophagus and pass up on either side, to end in two ganglia above, called the *cerebral* (or *brain*) *ganglia.* The earthworm has a highly developed sense of touch. Though without eyes, it can, with the anterior part of its body, distinguish between light and darkness. It has a slight sense of taste and of smell, but no hearing.

The earthworm bores its hole by passing the earth through its body, and backing out to leave it on the surface. This hole goes down often six or eight feet, and into it the worm retreats in the daytime, closing the opening with leaves and pebbles. It feeds upon vegetable matter, getting part of its nourishment from organic matter in the soil which passes through its body. It drags leaves into its hole, leaving them to soften and decay before using them.

Notes. 1. **The Intelligence** of the animal is displayed in the skill with which it gets a leaf into its hole. Crawling over it to determine its shape, the worm drags it by apex or stem, whichever will cause the leaf to curl up as it enters the opening.

2. **Benefit to Man.** — Darwin calculates that in some parts of England, earthworms, in boring, bring to the surface annually ten tons of subsoil to the acre. Besides this, the perforation of the soil allows air and water to permeate it. Leaves dragged underground help to enrich the soil, besides which, the earth which passes through the body is supposed to be slightly fertilized by the digestive fluid which is mixed with it. It will thus be seen that these little creatures materially assist the agriculturist, al-

though occasionally they injure young plants by drawing their leaves into the ground for food.

3. **At Surface during Rains.** — Earthworms come to the surface during rains, because their holes are flooded. They are often killed by heavy raindrops or hail.

Parasitic Worms. — Many forms among the worms are parasitic: among them is the *tapeworm*.

Slightly higher come the *threadworms*. These include the *Trichina*, the dangerous parasite occasionally found in pork; and the little worm *gordius*, which in early life is a parasite in an insect, but later develops in water into the so-called "*horsehair*" *worm*.

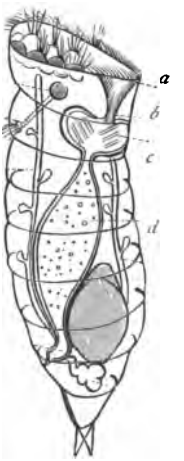

FIG. 28. — DIAGRAMMATIC REPRESENTATION OF THE ROTIFER: *a*, depression in the ciliated disk leading to digestive canal; *b*, mouth; *c*, pharyngeal bulb with masticatory apparatus; *d*, stomach.

A Microscopic Worm. — Then there is the interesting microscopic worm called the *rotifer*, from the rotation of cilia, which are in two circles on the head, and whose rapid vibration, resembling the rotation of wheels, whirls it about in the water, and draws food particles within reach.

Leeches and Sea Worms. — More closely related to the earthworms are the *leeches* and *sea worms*. The differences in their habits lead us to expect some difference in structure.

The leech has a sucker upon each end of the body. It has a head and eyes. The mouth has three internal teeth, by means of which the wound is made from which the animal draws its food.

The marine worm is fitted for its life in the water by flat, paddle-like gills along each side, a pair for every segment. These are also locomotive organs. The marine worm is carnivorous, devouring other members even of its own kindred, though it sometimes feeds on vegetable diet. Its mouth has a proboscis, which, when protruded, is seen to contain sharp teeth. Like the leech, the marine worm has simple eyes. The digestive apparatus is modified to suit the diet of the worm.

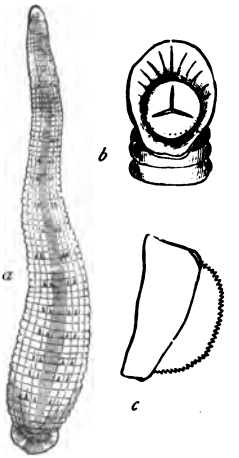

FIG. 29. — THE MEDICINAL LEECH: *a*, the leech itself (natural size); *b*, anterior extremity of same (magnified), showing sucker and triradiate jaws; *c*, one of the jaws detached, showing the semicircular toothed margin.

Notes. **1. Metamorphosis.** — In some worms the form of the young is quite different from that of the adult. It may therefore be said to go through a *metamorphosis.*

2. Brachiopods. — Some authorities place the brachiopods among the worms, while others refer them to *Molluscoidea.* They are better represented in fossil than in living forms. The bivalve shell gives them an external resemblance to the bivalve mollusks.

General Characteristics. — Body tubular, segmented, anterior and posterior regions distinctly marked; the digestive apparatus, a tube running through the length of the body; the nervous system ventral, with dorsal cerebral ganglia; the principal blood vessel dorsal; reproduction by means of eggs.

Suggestions for Review. — Compare an earthworm with a starfish in the arrangement of its parts. Compare this arrangement in the earthworm with the general plan of the human body. What difference between the relative positions of vital organs and nervous centers in the earthworm and in man?

CLASSIFICATION.

(*Branch.*)	(*Class.*)	(*Examples.*)
Vermes	Platyhelminthes	Flatworms, tapeworms.
	Nematelminthes	Trichina, horsehair.
	Rotatoria	Rotifers.
	Annulata	Earthworm, leech, marine worm.

Books for Reference.

Guides for Science Teaching, No. VII.
Sedgwick and Wilson's Biology.
Darwin's Vegetable Mould and Earthworms.
Kingsley's Standard Natural History.

BRANCH VI. — MOLLUSCA.

BIVALVES.

The Mussel. — One of the best-known animals in this branch is the *fresh-water mussel*.[1] Its soft unjointed body is covered by a muscular coat (the *mantle*), whose secretion builds up the shell which protects the animal. The substance of the shell is largely lime, but it also contains animal matter.

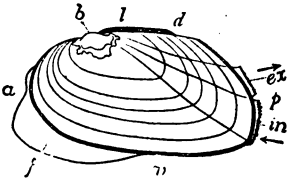

FIG. 30. — A FRESH-WATER MUSSEL: *l*, ligament; *b*, beak; *f*, foot; *ex*, excurrent orifice; *in*, incurrent orifice; *a*, anterior; *p*, posterior; *d*, dorsal; *v*, ventral.

The shell, being made of two pieces, is said to be a *bivalve*.

Since the halves are correspondingly alike, right and left, they are said to be *equivalved*. They show, however, anterior and posterior, dorsal and ventral, distinctions.

The joint between the valves is the *hinge*.

A horny elastic *ligament* unites them. Since this is external, its purpose is to pull the shell open.

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[1] The fresh-water mussel should not be confounded with the salt-water form, which differs materially from it in the structure of the shell and in the anatomy of the animal. It is somewhat unfortunate that the term "mussel" should have been applied to the fresh-water forms (*Unionidæ*), to which the animal just described belongs.

The hinge is on the *dorsal margin;* the opening of the shell is the *ventral margin,* or *base.*

The concentric parallel ridges on the outside of the shell represent successive additions, and are called *lines of growth.*

The point about which these are arranged, and from which the growth of each valve started, is called the *beak.* The beak points toward the anterior end of the shell.

To determine right and left valves, hold the shell with the hinge margin *up*, the beaks being pointed *away*, and the right valve will be to the right. This is the position in which the animal travels.

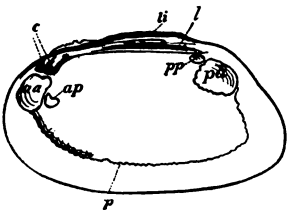

FIG. 31. — RIGHT VALVE OF A FRESH-WATER MUSSEL: *c*, cardinal teeth; *l*, lateral tooth; *li*, ligament; *aa*, anterior adductor impression; *pa*, posterior adductor impression; *ap*, anterior pedal muscular impression; *pp*, posterior pedal muscular impression; *p*, pallial line.

Examined interiorly, certain markings will be seen on each valve.

Close to the hinge certain prominences are called *teeth.* The teeth of one valve fit into grooves or depressions on the other.

Near the anterior and posterior region are the *adductor-muscle scars.* The adductor muscles are two in number, run straight across from one valve to the other, and by their contraction close the shell.

An irregular line on each valve, running from one muscle scar to the other, is called the *pallial line.* Within this the mantle and shell adhere closely; without, the mantle is free from the shell.

The shell is built up mainly by the secretion of the

edge of the mantle. The pearly lining is called the *nacre*, and serves to cover up the rough edges of the successive layers, which outwardly show in the *lines of growth*. An outer skin, or *epidermis*, covers the limy shell, and is secreted by the extreme edge of the mantle.

When the mussel dies, the adductor muscles no longer act, and the ligament contracting pulls the shell open. This is the condition in which dead shells are usually found.

The mussel lives usually in muddy places. It drags itself along by the *foot*, a muscular projection of the body extending through the anterior ventral part of the mantle. At the posterior end of the body, the edges of the right and left *lobes* or *leaves* of the mantle unite to form the *siphons*, — two short tubes whose lining is ciliated, and whose outer openings

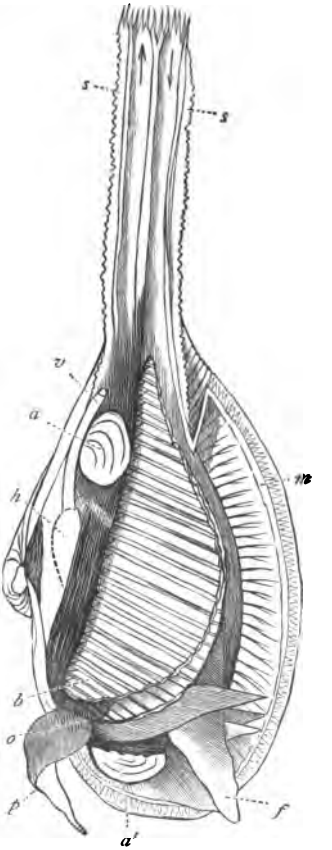

FIG. 32. — ANATOMY OF A BIVALVE. The left valve and mantle lobe, and half the siphons, are removed: *s*, respiratory siphons, the arrows indicating the direction of the currents; *a*, *a'*, adductor muscles; *b*, gills; *h*, heart; *o*, mouth, surrounded by labial palpi (*p*); *f*, foot; *v*, anus; *m*, cut edge of the mantle.

are fringed. The siphons and the foot may be extended or retracted at will.

The main body of the mussel lies between the mantle leaves. At the anterior end, between the adductor muscle and the foot or *pedal* muscle, is the small mouth opening, which is guarded by two pairs of triangular organs called *palpi*. The esophagus is short, leading into a large stomach. From the posterior end of this begins the long intestine, which winds about in the body between the other organs, finally ending close to the interior opening of the upper siphon. A large dark liver empties its secretion into the stomach.

The heart lies just below the hinge, on the dorsal side of the body, and consists of two auricles and one ventricle. The blood is a white milky fluid. Leaving the heart by arteries, it supplies the various organs, is then sent to the gills to be purified, and returns to the auricles, which really correspond to the left auricle of a four-chambered heart, divided for convenience.

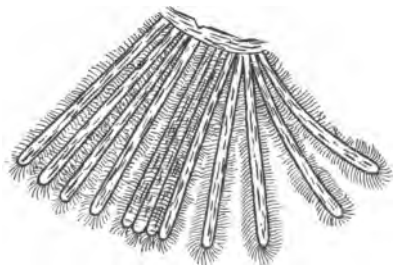

FIG. 33. — CILIA ON THE GILLS OF A MUSSEL.

Behind the palpi, along the lower border of the body, on each side, are two thin membranes with vertical parallel markings. These are the *gills*. They are covered with ciliated cells. The upper edges of the gills are attached to the interior of the leaves of the mantle. The inner gills from the two sides are united, inclosing between themselves and

the body an interior channel which leads to the upper siphon. Each gill consists of two layers of membrane, inclosing a cavity between them. These membranes are perforated.

Water enters the body by the lower or incurrent siphon, is carried over the gills by the movement of the cilia, penetrates their interiors through the perforations, and, its dissolved air being deprived of oxygen, the water escapes into the interior channel and out by the upper or excurrent siphon.

The food of the mussel consists of minute plants and animals which are in the water. Coming in contact with the gills, these little food particles are coated by a sticky mucus, and, guided by the cilia, gather into threads, which are carried forward till they reach the palpi, which pass them into the mouth.

The nervous system consists of three pairs of ganglia, — one just above the mouth, one above the foot, and one below the posterior adductor muscle. They are connected by nerve cords; and nerves from them supply the organs. The mussel has an ear located in the foot. It is a sac containing a fluid.

Reproduction is by eggs, which remain in the gills, and hatch there. The young forms, though possessing bivalve shells, are very unlike the parent, and are also carried by it in the gills for a time. After going through a metamorphosis, they assume the parent form.

The Oyster. — Another interesting bivalve is the *oyster*. This animal differs from the mussel in its habits, and therefore in its structure. During early life it is active, but before many days have passed, it selects a quiet spot,

where the water is clear and food stuff is abundant, and settles down, usually lying upon the left side. That valve soon becomes attached to the rock or another shell, and, unless forcibly removed, the oyster remains in this position for the rest of its existence.

Comparing the shell of the oyster with that of the mussel, the inequality of the valves will be noticed. The left is the larger and heavier, because it is the under.

The hinge is also quite different. The shell has its greatest length from hinge to base, and is broadest at the base. The left valve extends beyond the right at the hinge. The horny ligament, instead of being external, is in the joint between the valves, and is compressed when the shell is closed, but, when the adductor muscle relaxes, expands and forces the shell open.

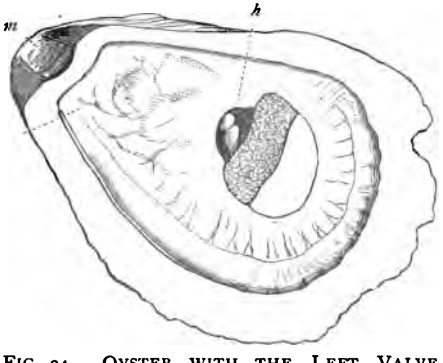

FIG. 34. — OYSTER WITH THE LEFT VALVE REMOVED: *h*, heart; *l*, ligament; *m*, position of mouth.

There is but one adductor muscle; and its scar, a black spot, is near the center of each valve.

The structure of the shell differs in another respect. Instead of the layers of growth being added near the edge of the shell, they form complete layers running back to the beak. This makes the shell much thicker at the beak than near the edge, while in the mussel the shell is of nearly uniform thickness.

The oyster differs from the mussel also in having no foot and no siphon. Water is drawn into the gills under the free edge of the mantle, its movement being caused by the action of the cilia, as in the mussel.

Oysters live in beds in shallow, quiet coves. A single oyster may in one season produce over a million eggs. In a few hours these become ciliated, free-moving forms, but within a week are permanently lodged. A large proportion of the eggs never reach maturity. They either fall a prey to fishes, or fail to find favorable conditions. Oysters are ready for the market in four or five years.

There are many species of oysters. Perhaps the most interesting is the *pearl oyster*. Off the coast of Ceylon, the fisheries for this oyster are very extensive and profitable.

Pearls are caused by foreign matter, such as sand grains, getting between the mantle and the shell. They so irritate the mantle as to cause an unusual amount of nacreous secretion, which forms about the foreign particle as a nucleus. The luster of the pearl depends upon that of the nacre usually secreted by the shell. Sometimes some animal bores into the shell of the oyster. In its efforts to keep out the intruder, the oyster secretes an unusual amount of nacre at the irritated point, and forms a "half pearl" on the interior of the shell.

Valuable pearls[1] are often found in fresh-water mussels. Their value depends not only on the luster and size, but also on the perfection of form.

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[1] The largest pearl in existence weighs three ounces, is four inches and one half in circumference, and is valued at sixty thousand dollars.

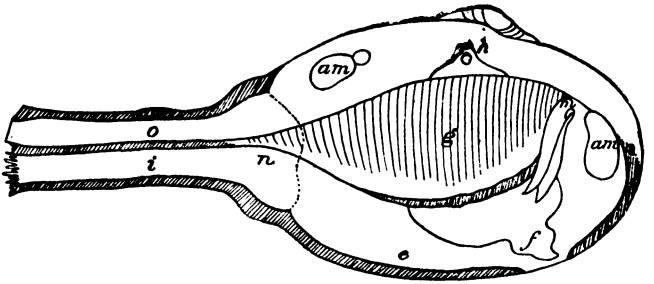

FIG. 35. — A CLAM WITHIN THE SHELL: *e*, edge of mantle; *f*, foot; *am*, adductor muscles; *m*, mouth; *h*, heart; *i*, inflowing siphon; *o*, outflowing siphon; *g*, gills; *n*, smelling nerve.

Other Bivalves. — Related to the oyster and mussel are *clams*, *scallops*, and many other bivalves; some with, and some without, the siphon.

UNIVALVES.

The Land Snail. — The common *land snail* has a *univalve* shell, growing spirally. The point from which growth starts is called the *apex*.

The turns in the shell are called *whorls*

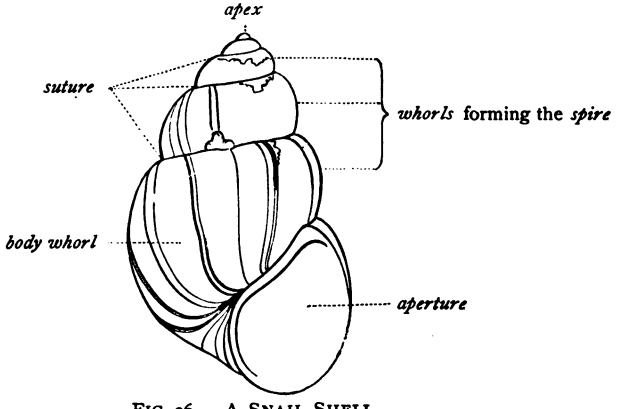

FIG. 36. — A SNAIL SHELL.

The whorls together form the *spire*, which may be *elevated, low, flattened*, or *depressed.*

The spiral groove between the whorls is called the *suture.*

FIG. 37.—A SNAIL SHELL, SEEN FROM BELOW.

The opening in the shell from which the body protrudes is called the *aperture* or *mouth*, and the free edge of this is called the *lip* or *peristome.* The edge formed by the body whorl is sometimes called the *columella.*

FIG. 38.—SINISTRAL SHELL.

Sometimes the edge of the lip (or peristome) is thickened or *reflected.*

White prominences on the peristome and on the body whorl, somewhat obstructing the aperture, are called *teeth.*

The center of the under side of the shell, the point just opposite the apex, is called the *umbilicus.* This is open in some, but closed by the lip in other species.

FIG. 39.—A SNAIL SHELL, SHOWING LINES OF GROWTH RUNNING PARALLEL TO THE EDGE OF THE APERTURE.

A shell whose spire twists to the right is said to be *dextral;* one turning to the left, *sinistral.* To determine this point, hold the shell, apex up, and aperture towards you: if the lip is to the right, the shell is dextral, and *vice versa.*

Like the bivalve, the univalve shell is covered and protected in life by an epidermis, which also gives its color.

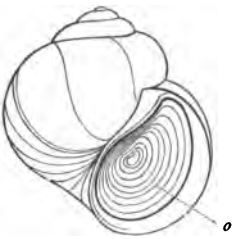

FIG. 40. — APERTURE OF SHELL CLOSED BY OPERCULUM, *o*.

In some snails (gill breathers) there is a limy piece called an *operculum*, which closes the aperture when the snail retreats within the shell.

The part of the snail protruded from the shell is called the *foot*. It is covered by an extension of the mantle. By allowing a snail to crawl upon a piece of glass, and watching the process from the under side, it will be seen that

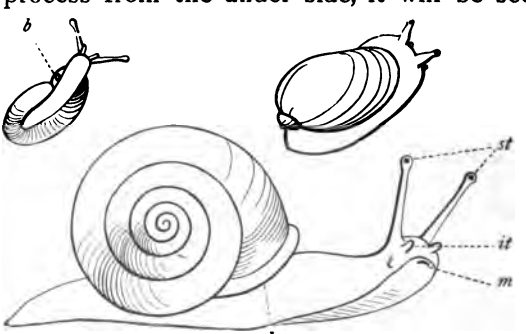

FIG. 41. — LAND SNAILS CRAWLING: *b*, breathing orifice; *st*, superior tentacles; *it*, inferior tentacles; *m*, mouth.

the snail lifts and shoves forward successive areas of this foot, the movement being wave-like.

Upon the forward end of the foot is the head. The snail has a distinct mouth, and a pair of *tentacles* for feelers. The land snail has a second and larger pair higher up on the head, and on the ends of these are the eyes. Both pairs can be withdrawn into the body.

Digestion. — The mouth has a hard upper jaw and lip, used to assist in biting. There is a *toothed tongue* or *lingual ribbon.* This consists of a long ribbon-like membrane growing from a cylindrical core (*odontophore*). The upper surface of the membrane is covered with rows of tooth-like processes pointing backwards. These are used in tearing or rasping the food. As the membrane gradually wears away at the outer end, it is supplied by growing from the core. The mouth of the snail leads into an esophagus. The other parts of the digestive apparatus are the crop, stomach, intestine, and the liver.

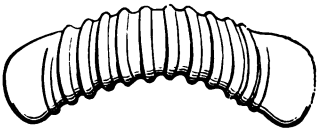

FIG. 42. — JAW OR BUCCAL PLATE OF A LAND SNAIL (HIGHLY MAGNIFIED).

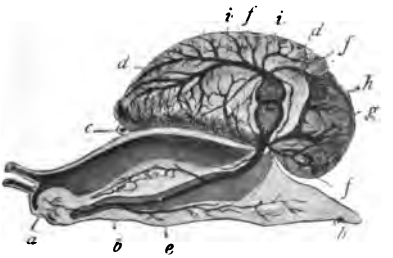

FIG. 43. — ANATOMY OF A SNAIL: *a*, mouth; *b*, feet; *c*, anus; *d*, lungs; *e*, stomach; *f*, intestines; *g*, liver; *h*, heart; *i*, vessels carrying the blood from the lungs to the heart.

Respiration is by means of a lung with a valve-like opening on the side of the body. This breathing pore is on the body just under the edge of the lip, and the lung in snails with dextral shells is therefore on the right side. It is simply an air sac.

The snail has a white-blood circulation, the heart being two-chambered, and the blood passing through it being arterial, as is the case in the bivalves.

The nervous system is similar to that of the bivalve. The eyes are not well developed, and are apparently as

much used for touch as for sight. There is an internal ear connected with the pedal ganglion. The snail has the senses of smell and taste, probably developed in some part of the skin, since no special organs for these have been discovered.

The skin of exposed parts of a snail is covered by a slimy mucus which is secreted by special glands. This mucus assists the snail largely in crawling.

Snails are usually vegetable feeders. During very cold or very dry weather, land snails retreat within their shells, and close the aperture by a membrane. A secretion of mucus containing lime is blown out over the aperture, something as a soap bubble is begun in the mouth of a pipe. The retreat of the animal forming a vacuum behind this membrane, it is pressed back to the level of the lip, and hardens there. Sometimes five or six successive membranes are formed for the protection of the animal against the cold.

The localities in which land snails hibernate are under leaves, rocks, or logs, in rotten wood, around the roots of trees and bushes, and sometimes buried several inches or a foot below the surface of the ground. They generally prefer woody places, especially shady banks of streams; but some are found in rocky places, others in open fields. On warm days in the early spring, they come out to sun themselves and to feed, and are often found at such times gathered together in numbers. Later in the season, they either retreat again to their hiding places, or are wandering about in search of food.

The snail reproduces by eggs. These vary in size with the species. They are nearly globular, and have often

limy shells. A single snail usually lays from thirty to fifty eggs at a time, and produces them three or four times during the season. The eggs are protected either by a capsule or a jelly-like covering. They are sometimes buried three or four inches under ground. The eggs take from twenty to thirty days to hatch, according to the season.

Other Univalves. — Related to the land snail is the *fresh-water air-breathing snail*, which comes to the surface of the water every time it needs more oxygen. This snail has the eyes upon the body instead of on tentacles, having only one pair of the latter. Its eggs are enveloped in a jelly-like substance, and massed together by it.

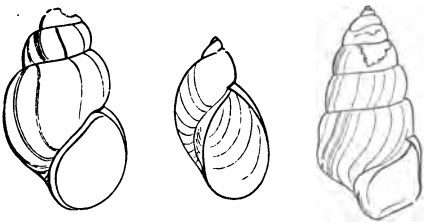

FIG. 44. — FRESH-WATER SNAIL SHELLS.

Another allied form is the *slug*, which is really a univalve, whose shell never receives any addition to the little

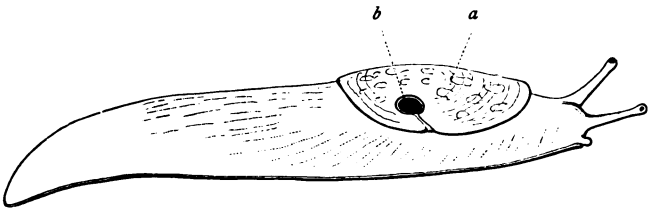

FIG. 45. — A NAKED LAND SNAIL OR SLUG, FULLY EXPANDED: *a*, mantle; *b*, breathing orifice.

scale-like piece with which the animal was born, and which soon becomes imbedded and hidden in the mantle.

Sea snails and some fresh-water snails differ from the land snail in breathing by gills.

Notes. 1. Shells are distinguished by the color, size, number of whorls; by the character of the spire, lip, and umbilicus; by the shape of the aperture, and the number and character of the teeth. The character of the epidermis, whether smooth, rough, or hairy, and the distinctness of the marking of the lines of growth, also serve as distinguishing features.

2. The slimy secretion from slugs is so tenacious, that by means of it they suspend themselves from high places, the mucus hardening into a thread-like cobweb.

CEPHALOPODA.

The Cuttlefish. — This may be taken as a type of the highest mollusks. It has no external shell, but its body is supported internally by a curious structure, — the "cuttlefish bone" frequently seen in bird cages. This consists of a hard layer of shell, slightly hollowed, and the hollow filled with a chalky substance. This lies on the dorsal side of the animal.

FIG. 46. — CUTTLEFISH (ONE FIFTH NATURAL SIZE).

The mantle covers the body except the head. It is a loose, somewhat conical case, fastened to the body only in a line along the back From the broad open end of the cone projects the head.

Upon the head, around the mouth, are ten long arms or tentacles. Eight of these are armed with suckers along their entire length. Two, which are longer than the rest, have suckers only at their ends. These suckers have circular rims, and within each a central disk that acts as a piston. When the suckers are applied, the prey is securely held.

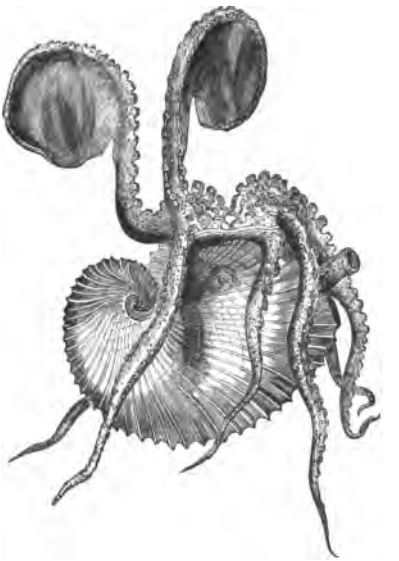

FIG. 47.—THE FEMALE ARGONAUT. The animal is represented in its shell, but the webbed dorsal arms are separated from the shell which they secrete, and which they ordinarily embrace.

The gills of the cuttlefish are in the mantle cavity. The free edge of the mantle around the neck is usually open to admit water to the gills; and for breathing purposes, water enters and is expelled from this region. Connecting with the mantle cavity, in the middle front part of the neck region, is a tube (or *siphon*). The free edge of the mantle may be brought against the neck, so that the ordinary egress of the water is prevented, and it is then forcibly expelled through the siphon. By the reaction produced when water is thrown forward from it, the animal is carried backward, and usually retreats with its face to its foe. It may, however, bend the end of the siphon, and reverse the direction of its movement. The cuttlefish

has in its interior an ink bag, whose very black secretion may be poured into the mantle cavity, close to the inner end of the siphon. When the siphon is in use, the ink may be expelled with the water, and so cloud it as to blind the enemy, and cover the retreat of the cuttlefish.

From a cuttlefish's ink bag comes the true sepia used by artists, though an imitation sepia is manufactured. The ink from the bags of fossil forms may still be used.

FIG. 48. — THE SQUID.

The mouth of a cuttlefish is armed with horny, parrot-like beaks, and a toothed tongue.

The brain is large, and protected by a cartilaginous case. The pair of large eyes on the head are very well developed, and below each eye is a pit supposed to be an organ of smell. Internal ears are also present.

Other Cephalopoda. — Allied to the cuttlefish, and much like it, is the *arrowfish* (or *squid*).

Resembling the cuttlefish in its shell-less body, but differing entirely in form, is the eight-armed *devilfish* (or *octopus*), whose equal tentacles are used in crawling.

The pearly shell of the *nautilus* is coiled and chambered. The animal lives in the outer chamber, but retains its connection with the others by a fleshy tube or *siphuncle*, which penetrates all the septæ, and ends in the innermost chamber. These chambers are filled with gas, whose presence is not easily accounted for. It is sup-

posed to act in the same way as that in the air bladder of the fish.

Another famous shelled mollusk is the *argonaut*, whose shell is not attached to the body, but is simply a loose case. Two of the eight tentacles of the female are broad and sail-like, and are thrown outward and downward to envelop her body and protect the eggs and young. An excretion, partly from these membranous arms and partly from the mantle, builds up the beautiful frail shell. The male argonaut is shell-less.

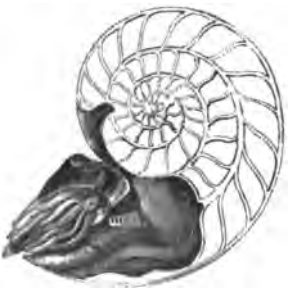

FIG. 49. — PEARLY NAUTILUS, WITH SHELL CUT OPEN.

Most of these forms, like the cuttlefish, are provided with siphons.

General Characteristics of Mollusks. — A mollusk is an animal with a soft, unjointed body covered wholly or partly by a mantle, and frequently further protected by a shell. It has white blood, the heart being dorsal. The nervous system has its centers in three main ganglia, which lie among the viscera. Reproduction is either oviparous or viviparous.

Suggestions for Review. — Compare the oyster with the clam, showing how difference in structure corresponds to difference in habit. Compare a mussel with a land snail. In what respects is the latter more highly organized? Compare the snail with the cuttlefish. Why is the latter placed in the highest class of mollusks? Compare a slug with an earthworm. The slug is somewhat like a worm in form, and often mistaken for one: why is it classed with mollusks instead? In what respects is a snail more like a worm than like a sea anemone?

CLASSIFICATION.

(*Branch.*)	(*Class.*)	(*Examples.*)
Mollusca	Lamellibranchiata or Bivalves (Acephala)	Oyster.
		Clam.
		Mussel.
	Gasteropoda or Univalves (Cephalophora) . . .	Sea snails.
		Land snails.
		Pond snails.
		Slugs.
	Cephalopoda	Cuttlefish.
		Squid.
		Octopus.
		Nautilus.
		Argonaut.

Books for Reference.

Guides for Science Teaching, No. VI.
Needham's Lessons in Zoölogy.
Martin and Huxley's Practical Biology.
Binney's Manual of Land Snails.
Kingsley's Standard Natural History.

Instructions to Collectors.

The best time to collect land snails is on warm days in winter, or in the early spring, especially after a rain. They must be searched for under logs, stones, or piles of leaves which collect in little hollows, especially on the shady slope of a ravine. Some varieties, however, choose rocky, exposed slopes. Almost all river banks prove fertile fields for such collecting. Very small forms are found under the bark of trees, among the roots of grass, and in moss. There is scarcely a locality where careful search will not at some season discover them.

On starting out, the student should arm himself with one or two close tin boxes and a small flat bottle of dilute alcohol (one

third water), into which the very small shells may be put at once. A good knife is another essential. A small hatchet, with a hook-like end opposite the blade, will help in turning over rocks, breaking up logs, etc.

Water snails are found in mud and gravel in the bottom of streams, ponds, or ditches, or floating on the surface of the water. They can best be reached by using a perforated dipper with a long handle. By means of this, the mud and sand may be sifted and washed off the snails. A pair of rubber boots enables one to collect specimens that could not otherwise be reached without wet feet.

In collecting fresh-water mussels, the student will have best success if he will choose a time when the water is low in the river or stream he intends to explore. Mussels will be found nearly buried in muddy or sandy bottoms, or hiding between rocks in the bed of streams. A few should be kept alive in a tank, to be studied. By putting a mussel in boiling water, it will loosen its hold upon the shell, which opens. If it is then thrown into cold water, the mussel contracts, and may be removed from the shell with the hand. If hot water cannot be had, a knife slipped between the mantle and the shell, to cut the adductor muscle, will open it. This is, however, a slow process.

To clean snail shells, the best plan is the following: If land snails, expose them in a warm room, having sprinkled them a little. Soon they will come out of their shells. Drop a few at a time in boiling (*not merely hot*) water. Remove, and with a bent pin (or, better still, a bent wire thrust into a soft pine handle) draw out the snail. The pin or wire must be inserted into the shell as far as possible to do this. Experience will teach one how long each species should remain in the water to be most easily removed. The average time is less than a minute. Small snails may have a loop of thread thrown over the body close to the shell, before dropping into the water. This can be used to draw out the animal. The shells should then be thoroughly brushed with a nail or tooth brush. A syringe will help in cleaning the interior. Shells from which dirt cannot easily be removed may be

put into a test tube or wide-mouthed bottle, and a small quantity of sand and water shaken up with them. The sand often scours them quite clean. Iron stains may be removed from water shells by shaking them in a saturated solution of oxalic acid. No shell should be allowed in any collection that is immature, imperfect, or dirty. If the epidermis is disappearing, the shell has lost its chief beauty. As this soon wears away when a dead shell is exposed to the influences of the weather, only shells taken from live animals are admissible.

The luster of water shells may be improved by rubbing them with a few drops of linseed oil, but this and the acid *should never be used on land shells.*

BRANCH VII. — ARTHROPODA.

CRUSTACEANS.

THE jointed-legged animals, or *Arthropoda*, fall into two great groups, *Crustaceans* and *Insects*. We will first consider the Crustaceans.

The Crawfish. — A very familiar form of crustacean is the *crawfish*, whose limy external skeleton resembles a

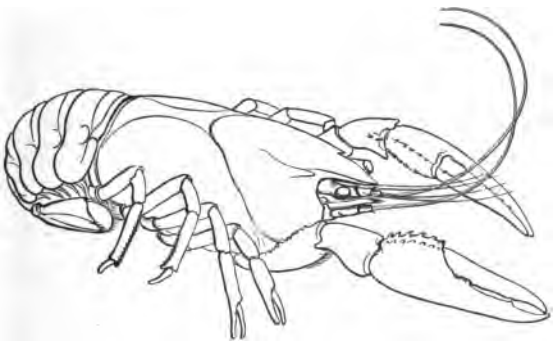

FIG. 50. — FRESH-WATER CRAWFISH FROM THE MISSISSIPPI RIVER.

crust, and proves the appropriateness of the name of the class. The body consists of two general regions, the *cephalothorax* and *abdomen*. The former is covered by a single piece, the *carapace;* the latter is distinctly segmented, and capable of being doubled under the body.

The whole body of the crawfish is segmented, though the divisions of the cephalothorax are not so evident as those of the abdomen. The body has twenty pairs of appendages, one pair to every segment. The first pair consists of *stalked eyes;* the second, the *antennæ.* Then come the *antennules,* next the *mandibles* (or jaws), and two pairs of *maxillæ* (or assistant jaws). These constitute the appendages of the head proper. Then come three pairs of *maxillipeds* (or foot jaws), a pair of large *claws,* and four other pairs of *feet.* These are the thoracic appendages. The six pairs of *swimmerets* and the *telson* (or tail) are the abdominal appendages.

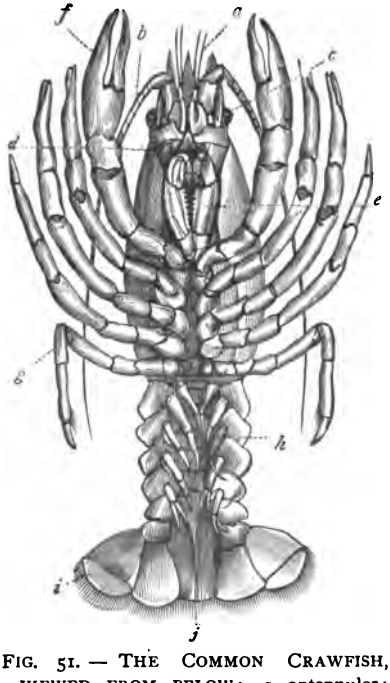

FIG. 51. — THE COMMON CRAWFISH, VIEWED FROM BELOW: *a*, antennules; *b*, large antennæ; *c*, eyes; *d*, opening of auditory sac; *e*, last pair of foot jaws; *f*, one of the great chelæ; *g*, fifth thoracic limb; *h*, swimmerets; *i*, last pair of swimmerets; *j*, opening of the anus below the telson.

The mouth opening of the crawfish is in the direction of the length of the body, the paired mouth parts being on either side of the middle line. Food broken up by the mandibles and maxillæ passes down a wide esophagus into the stomach. This stomach has three parts. The first, or

cardiac, has thin membranous walls; further on, the walls are hard, jointed, and toothed, having strong muscles which move them so as to further grind the food. The

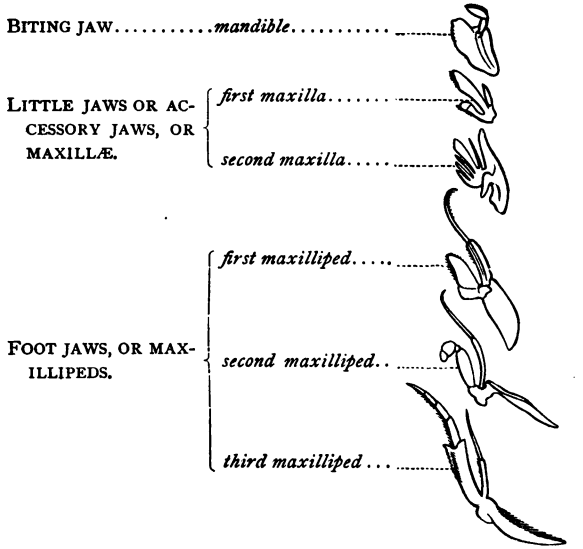

FIG. 52.—MOUTH PARTS OF A CRAWFISH, FROM THE LEFT SIDE.

pyloric part of the stomach is narrow, and its walls are thickly covered with hairs, which prevent any but very fine and soft food from escaping into the slender intestine.

FIG. 53.—A BIG CLAW OF THE LOBSTER.

The heart lies in the middle of the dorsal region, under the carapace, the white blood returning to it after being

purified. Thus, as in the mollusk, it corresponds to the *left* side of a four-chambered heart.

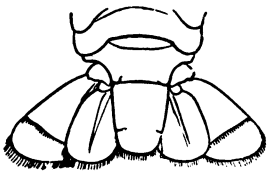

FIG. 54. — TAIL OF CRAWFISH, SHOWING FLATTENED APPENDAGES FOR SWIMMING.

The breathing organs are gills, which are under the carapace, at the sides of the body, and attached to the upper joints of the legs. Water entering the gill cavities under the edge of the carapace is thrown out in front by a gill bailer, which is attached to the base of the second pair of maxillæ. This gill bailer is constantly scooping the water forwards from the gill chamber, and this keeps a current moving over and between the gills.

The nervous system of the crawfish consists of a ventral chain of ganglia. One large ganglion lies above the esophagus, and is usually called the *brain*. Its fibers divide into two bundles that pass, one on each side of the esophagus, and unite in the next ganglion of the chain. The only apparent organs of special sense are the stalked and movable eyes, and an ear on the upper side of each antennule. This consists of a cavity whose opening is protected by close hairs. Within the cavity is a membranous bag containing a fluid and

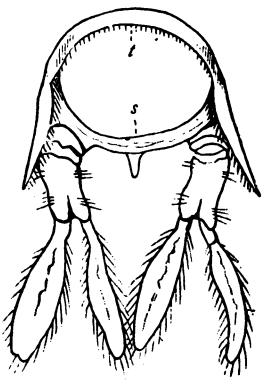

FIG. 55. — THIRD ABDOMINAL SEGMENT OF THE LOBSTER: *t*, dorsal arch; *s*, ventral arch of the segment.

the ending of the auditory nerve. Since the covering of the crawfish is such a hard crust, especial provision is made for touch in the antennæ, and in the fringes which are attached to all the joints and free edges of the parts.

The crawfish molts, or sheds his crust, whenever it becomes too small for his body. At first, during the rapid growth of the young animal, it molts frequently;

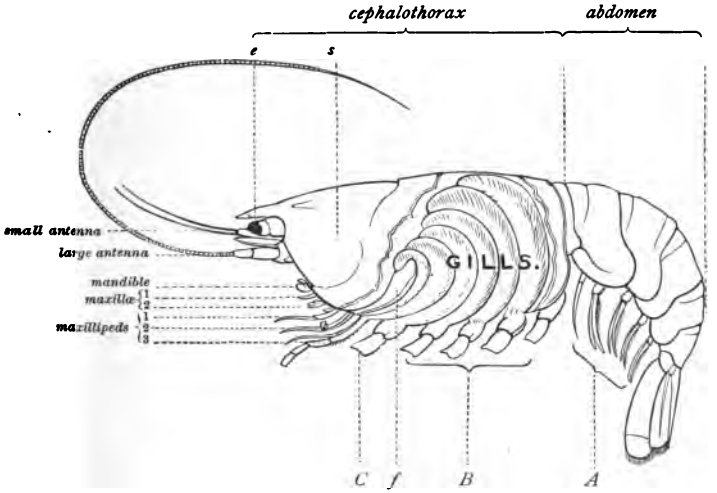

FIG. 56. — CRAWFISH (SIDE VIEW), WITH PORTION OF CARAPACE REMOVED WHICH COVERS GILLS (APPENDAGES OF LEFT SIDE ONLY SHOWN): *s*, region of stomach; *A*, abdominal appendages; *B*, bases of the four small legs; *C*, base of large claw; *f*, gill bailer attached to the second maxilliped; *e*, eye.

later on in life it molts but once a year. The animal, when about to molt, seeks a retired spot. The joint between the carapace and abdomen usually opens, and by hard effort the crawfish wriggles out of his shell. In this condition his body is soft and unprotected; and, weakened by the effort to cast off the old crust and form

a new, he is an easy prey to his enemies. It probably takes about a week to form the new crust.

Crawfishes reproduce by eggs. These remain attached to the swimmerets of the mother; and thus she carries them, and also the young, about with her. Young crawfishes closely resemble the parent form.

Other Crustaceans. — Very closely resembling the crawfish in structure are both the *lobster* and the *shrimp*.

Related, but not so nearly like it, are *crabs* of all kinds, the *beach flea*, *water flea* or *cyclops*, *sow bug* or *pill bug*, *barnacle*, *horseshoe crab*, *brine shrimp*, and others.

Notes. 1. **The Hermit Crab.** — One most curious form is the *hermit crab*. This animal starts in life with organs similar to other crustaceans; but, preferring to avoid rather than face the dangers usually attending a crab's existence, he soon finds an empty sea shell or other retreat, into which he backs, occupying it as long as it will accommodate his growing body. This animal well illustrates the economy of nature. Organs which in his retired life are not used are left undeveloped or withdrawn entirely. Only the appendages near the head are much developed. The abdomen has no crust, and very imperfect appendages. When one home becomes too small, the hermit crab secures another and larger one.

2. **The Sow Bug** (or pill bug) is the little, dark, insect-like animal, which is common in dark, damp, or musty places, such as in cellars, or under boards, dead leaves, etc. Its habit of rolling itself, when disturbed, into a perfect little sphere, has given it the name *pill bug*.

3. **The Trilobite.** — Related closely to the horseshoe crab is an interesting fossil form, the *trilobite*.

General Characteristics. — A segmented body, covered with a limy crust; numerous appendages, arranged in

pairs; body divided into two general regions, cephalothorax and abdomen, the former usually covered by a carapace; heart dorsal; nervous system ventral; mouth opening in the direction of the length of the body; breathing generally by gills.

INSECTS.

HEXAPODA, OR SIX-LEGGED.

COLEOPTERA, OR SHEATH-WINGED.

The June Beetle. — A familiar and typical form among the insects is that of the little beetle called the *June bug*.

Its body is made up of three general regions (*heaa, thorax*, and *abdomen*), with their *appendages*. The skeleton is external. It consists of a hard substance, called *chitin*, developed in the skin. The body is segmented, consisting of four segments in the head, three in the thorax, ten in the abdomen. Only in the last is the segmentation very apparent.

FIG. 57. — JUNE BEETLE, SHOWING HOW MEMBRANOUS WINGS ARE FOLDED AWAY.

Upon the head are one pair of *antennæ* (or feelers). A *labrum* (or upper lip) overhangs the other mouth parts, which consist of *mandibles* (or jaws), *maxillæ* (or assistant jaws), and a labium, which is really composed of a second pair of maxillæ united to form one piece. Attached to the maxillæ and labium are two pairs of *palpi* (or sense

organs). Within the mouth is a membranous, spiny *tongue* (*ligula*).

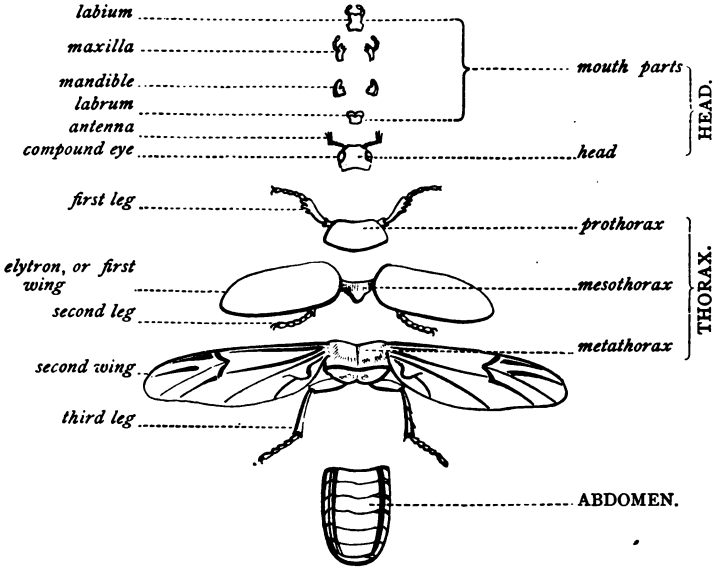

FIG. 58. — A COMMON BROWN BEETLE, WITH THE PARTS SEPARATED.

The divisions of the thorax are called *prothorax*, *mesothorax*, and *metathorax*. The first bears a pair of jointed *legs;* the second, a pair of wings and another pair of legs; the third, the second pair of wings and a third pair of legs. The fore wings (called in the beetle *elytra*) are horny, and are not used in flight except to balance or steer the body, but act as a protection to the membranous hind wings. During flight they are spread at right angles to the body. The hind

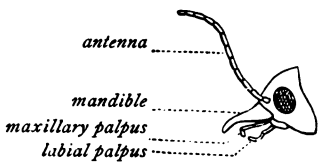

FIG. 59. — HEAD OF BEETLE, SHOWING MOUTH PARTS.

wings are the true organs of flight, and fold beneath the elytra when not in use. The elytra of the June bug are brown.

The leg of the June bug consists of two short joints near the body, then two longer ones called *femur* and *tibia* respectively, and a *tarsus* or *foot* of five joints, the last armed with two claws.

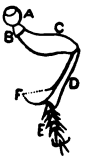

FIG. 60. — LEG OF AN INSECT PROPER: *A*, coxa; *B*, trochanter; *C*, femur; *D*, tibia; *F*, tibial spurs; *E*, tarsus, composed of five tarsal joints, the last one ending in a claw.

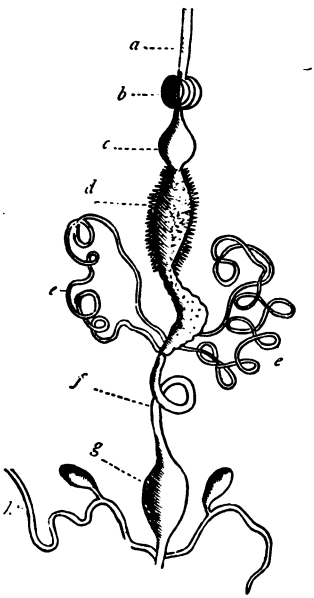

FIG. 61. — DIGESTIVE APPARATUS OF A BEETLE: *a*, gullet; *b*, crop; *c*, gizzard; *d*, chylific stomach; *e*, Malpighian tubes; *f*, intestine; *g*, cloaca; *h*, anal glands.

The digestive apparatus consists of a narrow esophagus into which the saliva is poured, a crop, a gizzard armed with chitinous teeth, a stomach, and an intestine.

The beetle breathes by means of air tubes or tracheæ, which penetrate every part of the body, even the legs and wings. These tubes are strengthened by closely wound spiral threads, which form the middle layer. The air does not enter the tracheæ through the mouth of the beetle, but through a series of openings (ten pairs)

called *spiracles*, along the sides of the thorax and abdomen.

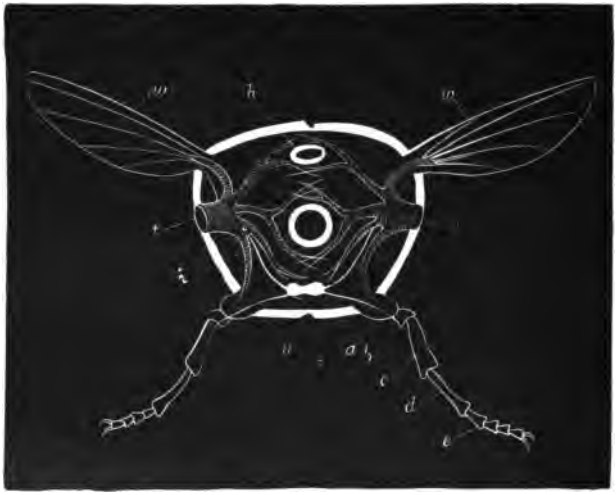

FIG. 62. — IDEAL TRANSVERSE SECTION OF AN INSECT: *h*, dorsal vessel; *i*, intestine; *n*, ventral nerve cord; *t*, stigmata leading into the branched tracheal tubes; *w*, wings; *a*, coxa of one leg; *b*, trochanter; *c*, femur; *d*, tibia; *e*, tarsus.

Each opens by a double valve into a *vestibule*, and has a strainer of fine hairs to prevent the entrance of foreign substances. Connecting with the tracheæ are *air sacs*, which give buoyancy to the body during flight, being inflated and emptied at will.

FIG. 63. — TRACHEÆ OF AN INSECT, SHOWING ELASTIC SPIRAL THREAD.

The heart of the beetle is a long, many-chambered organ, lying above the intestine. It forces the blood forward into an aorta which runs toward the head. There are no smaller arteries, capillaries, and veins, but the blood finds

its way through the tissues back to two veins which empty into the posterior part of the heart.

The beetle has a well-developed and complicated muscular system.

The nervous system consists of a chain of nine ganglia on the ventral side of its body, and one dorsal ganglion, the brain.

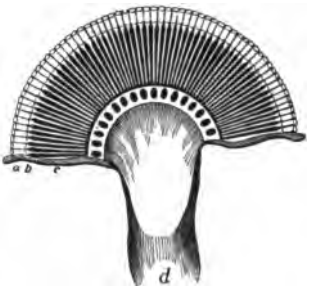

FIG. 64. — SECTION OF THE EYE OF THE COCKCHAFER (HIGHLY MAGNIFIED): *a*, facets of the corneæ; *b*, pyramids surrounded with pigment; *c*, fibers of the optic nerve; *d*, trunk of the optic nerve.

The special senses are fairly well developed. Two eyes are compound, consisting of many facets. Besides these, are three simple eyes or *ocelli*. The antennæ are organs of touch, and also of smell, which sense is very acute. The ears have not been discovered, but it is known that the beetle has hearing. It produces sound by rubbing together hard parts of its body.

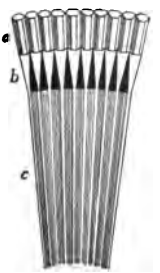

FIG. 65. — A PORTION OF THE PRECEDING FIGURE (MORE HIGHLY MAGNIFIED).

The beetle is developed from an egg which has a thin, limy shell. At first it is a little worm-like form which has very little apparent resemblance to the parent. This little "worm," called the *larva*, differs from a true worm in having a distinct, well-developed head and mouth parts, three or four

pairs of ocelli, and three pairs of thoracic legs. The June-bug larva is white. It lives in the ground, and often does great damage to turf. It cuts the roots of strawberry plants also. After living as a larva for two years, feeding voraciously, and shedding its skin whenever it becomes too small for the rapidly growing body, the June bug goes into a second or *pupa* state, in which it is apparently lifeless. It becomes covered with a hard skin. During this stage it remains under ground; but at the end the pupa skin bursts, and the perfect winged form (or *imago*) emerges, and appears above ground. These changes of form, common to many insects, constitute its *metamorphosis*. The June beetle attacks and devours the leaves of fruit trees, especially the apple and the cherry.

Other Beetles. — More or less closely allied to the June beetle are many other beetles, such as the *ladybirds*, *leaf eaters* (including the *potato bug*) the *longicorns* (whose larvæ often do great damage to the trees into which they bore), the *burying beetles* (which undermine and then cover carrion, and so benefit mankind), the *blister beetles*, *weevils*, *glowworms* or *fireflies*, *spring beetles*, the *tumble-bugs*, *ground beetles*, *diving beetles*, *tiger beetles*, etc.

It is said that there are more than eighty thousand species of beetles known. Another authority estimates one hundred and twenty thousand. The larval and pupal stages of many beetles are spent underground, the larva being then called a *grub*. During this stage it is often very destructive to the roots of plants.

What has been said of the structure and development of the beetle will apply to most other insects; the most apparent points of difference between them being in the

development of the wings, antennæ, and mouth parts, and in the presence of different abdominal appendages.

Notes. 1. **The Veins** in the wings of insects consist of double tubes: the inside is a trachea; and the space between it and the outer is filled with blood, which is there aërated.

2. **The Colorado Potato Beetle** is probably as well known as any for its destructive habits. A native of the Rocky Mountains, it fed, up to the year 1859, upon a wild plant, the sand bur, a species of wild potato; but upon the introduction and cultivation of the potato in Colorado, so well did it thrive upon this plant, that the beetle spread rapidly, and before many years became the scourge of the whole country. The female lays from five hundred to one thousand eggs in a season, placing a few at a time on the under side of a leaf. It takes about a week for the eggs to hatch, and immediately the larva begins its work of destruction. It feeds for about two weeks, and then buries itself in the ground to pass the ten days of the pupal stage. The imago is as active as the larva in devouring the potato plant; and as four broods can be produced in a season, and as the insects also hibernate, their multiplication is extremely rapid. The means used to exterminate this insect is generally to spray the plant with a diluted preparation of arsenic, and many different machines have been devised to facilitate the work.

FIG. 66. — COLORADO BEETLE. EGGS, LARVA, ADULT.

3. **The Tumblebug.** — Our common *tumblebug* protects its egg by placing it within a spherical ball of earth or dung, which is buried in a hole prepared for it. In rolling the ball, the male beetle pushes, and the female pulls, the fore legs being differently developed for the purpose. When the egg hatches, the larva feeds upon the organic matter in the ball in which it was placed.

4. **The Spring Beetle.** — One of the *spring beetles*, or *snapping beetles* (*Alaus oculatus*), is about an inch and a half in length, and colored black and white. Upon the prothorax are two velvety black spots, surrounded by white rings, which are often mistaken for its eyes. It receives its common name from the fact that, when turned upon its back, it springs into the air, and regains its proper position. The larvæ of some spring beetles are called *wireworms*.

5. **The Firefly,** as is well known, emits a light from its abdomen. The cells of the luminous organ secrete some substance that becomes luminous when acted upon by oxygen. This gas is supplied through the tracheæ, and the emission of the light is under nervous control.

6. **The Ladybird** (or *lady beetle*) is very useful to man, since both the larva and the imago feed upon the eggs, larvæ, and imagoes of other destructive insects, — such as scale insects and plant lice, — and one species even devours the eggs of the Colorado potato beetle.

7. **The Water Beetle** (*Hydrophilus triangularis*) is about an inch and a half long, and is black and shiny. Its legs are flattened for swimming. It breathes by taking in air particles held along the hairy underparts. This air is often renewed by the insect's return to the surface of the water. The female covers her eggs with a cocoon of a hardened jelly-like secretion. This cocoon has an inner and an outer case, and is attached to a curiously shaped floater. The larvæ, when hatched, are carnivorous, eating insects and snails, and, for lack of other food, will prey upon each other. Their pupa stage is passed in the ground.

8. **The Larvæ** of many beetles do a great deal of damage to trees by boring into the wood. Instinct causes each female to place her eggs close to the food best suited to the larva.

General Characteristics. — Head, thorax, and abdomen distinct; mouth parts developed for biting; fore wing horny (*elytron*); hind wing gauzy, folded (when not in use) beneath the fore wing; metamorphosis complete.

NEUROPTERA, OR NERVE-WINGED.

The Dragon Fly, also called *devil's darning needle, snake feeder,* and *mosquito hawk,* is an insect with long, slender body, widely spreading, thin, net-veined wings, and very beautiful dark metallic colors, which are less brilliant in the female than in the male. The head is large, and the eyes are enormous.

FIG. 67. — DRAGON FLY.

Its eggs are laid in the water, where the larval and the pupal stages are passed. The larva has the mouth parts well developed; but the labium is so large as to completely hide the others when folded over them. Then the insect looks very harmless; but this labium is capable of great extension, and armed with hook-like palpi for seizing other insects, and the larva is so voracious that it is often called a *water tiger.* It has the three pairs of thoracic legs developed for crawling. Gills are located in an abdominal cavity with a valve-like opening at the end of the abdomen. Water admitted to these (according to some authorities) may, by a sudden muscular contraction,

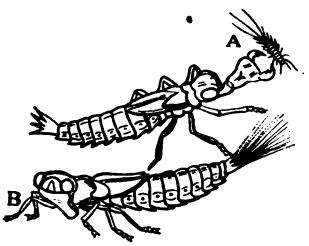

FIG. 68. — *A*, Dragon-fly larva seizing its prey; *B*, Larva with labium folded over mouth parts.

be ejected with force enough to carry the insect forward. The pupa is only a larger form produced after molting. During this stage the insect is still active.

When about to change into the imago, the insect climbs some plant, and so gets out of the water, the pupa skin splits along the back, and the winged form emerges. In an hour its wings are spread and dry, and the insect flies away.

Other Neuroptera. — Related to the dragon fly are the *May flies*, *caddis* or *case flies*, *white ants*, *ant-lions*, *aphis lions* or *lace-winged flies*, etc.

Notes. 1. **The May Fly** is another form whose larval and pupal stages are passed in the water. It lives so for two years, after which the imago emerges from the pupa case and leaves the water, the female dropping its eggs as it flies. This insect takes no nourishment in the imago state, and its life in this condition is short, usually not over two days.

2. **The Case Fly.** — Another insect whose larva and pupa live in the water is the *case fly*. As a larva, it constructs a tube of sand, leaves, etc., which covers the abdomen. In the pupa state, the case protects the whole body. The imago, which looks like a small moth, bites its way out of the case through the netting that has been spun over its mouth.

3. **The White Ants** mimic the true ants to such an extent, both in habits and appearance, that they are popularly classed with them. They live in colonies in the trunks of dead trees, in wooden structures, or in timber of any kind. The colony contains four kinds of individuals, — winged males and females, soldiers and workers which are wingless. The soldiers, which are brown in color, have large heads and powerful jaws. The workers are smaller and white. The winged forms have brown bodies and white wings. In tropical countries these white ants do much damage by eating into furniture, walls of houses, etc.

4. **The Ant-lion** in its larval stage lives in the sand. It has powerful jaws, and feeds upon ants, which it captures in a curious way. It hollows out a conical pit in the sand by whirling itself about. It then lies concealed at the bottom of the pit, watching for its prey. An unwary ant, inspired by curiosity, peers over the edge of the pit. Immediately a movement of the ant-lion's body causes the sand to slide, bringing down the unfortunate ant within reach of his enemy's jaws. This predatory life is pursued for at least two years. A silken cocoon protects the insect during the brief pupal stage. The imago resembles the smaller dragon flies in general appearance.

5. **The Aphis Lion** is so called because in its larval stage it preys upon aphides (or plant lice). Its imago has beautiful pale green wings, slender body, and yellow eyes.

General Characteristics. — Long, lacy, reticulated, gauzy wings; slender body; mandibles well developed in both larva and imago; and metamorphosis only partially complete.

ORTHOPTERA, OR STRAIGHT-WINGED.

The Grasshopper. — Another well-known insect is the *grasshopper*. The common name, "grasshopper," is rather indiscriminately applied to insects belonging to two different families, — the long-horned (or meadow) grasshoppers to one (*Locustidæ*), to which also belongs the katydid; and the short-horned grasshoppers, which are more properly called locusts, to the other (*Acrididæ*). The locust has a narrow or compressed body. The fore wings are straight and somewhat thickened to protect the large, gauzy, hinder pair, which are folded like

FIG. 69. — GRASSHOPPER.

a fan when not in use. The hind legs are long, and adapted for leaping. The head is large, and the mouth parts are adapted for biting. The compound eyes are small and far apart. The antennæ never exceed the body in length. The prothorax is large in proportion to the other thoracic segments.

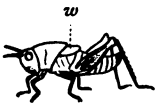

FIG. 70. — YOUNG GRASSHOPPER: *w*, wing just appearing.

In the female there is at the end of the abdomen an *ovipositor*, consisting of four sharp points. These are first used to bore a hole in the ground, and then to guide the eggs into it.

The digestion of the grasshopper and all other biting insects is much like that of the beetle. The salivary glands of the grasshopper are unusually well developed, and their secretion is the so-called "tobacco juice" of the insect.

The nervous system is also similar to the beetle's. The ears, however, are located on the first segment of the abdomen; and each consists of a drum, an internal fluid, and a supply of nerve filaments.

The eggs of the grasshopper are laid in a mass of from fifty

FIG. 71. — CAST-OFF SKIN OF A GRASSHOPPER. The grasshopper has shed its skin while clinging to a blade of grass. The skin is imperfect; the antennæ and parts of its legs are broken; the abdomen is shriveled, and does not show.

to a hundred, and protected by a thick, gluey secretion. The young insect resembles the parent in most respects, except that it is smaller and wingless. In the pupal stage, wing pads are noticeable. The metamorphosis consists only in a succession of molts, and is said to be "incomplete."

Notes. 1. **The Cockroach.** — The most disgusting insect, the *cockroach*, is related to the grasshopper. Species of this insect are native in many parts of the world; but, since they infest ships, there are some species which have followed man everywhere. These differ in size, coloring, development of wing, and in some of their habits. In the daytime they lurk in dark, damp places, especially around pipes or in cracks and crevices, coming out to feed at night. They are omnivorous, and will devour not only food intended for man, but cloth, books, and other valuable articles, and, for lack of other food, will even devour other species of their own kind. Their eggs are laid in a leathery capsule, which at first is white. This is carried by the female until the young are ready to emerge. Young roaches molt several times, and after each molt are perfect albinos for a short time.

2. **The Mantis.** — In the Southern and Western States, as well as in tropical regions, is found an insect (also related to the grasshopper) called the *mantis*. From the peculiar position of its fore legs when waiting for its prey, it is called *rear-horse*, *praying insect*, and *soothsayer*. It should more properly be called preying insect, since it is a genuine cannibal, the members of one family devouring each other. The mantis has a slender body and very large eyes. The large elongated front legs are strong, spiny, and not used much in walking, being at that time held folded, but they are employed to seize and hold the prey.

3. **Walking Sticks and Walking Leaves.** — The grasshopper has other curious relatives in the *walking sticks* and *walking leaves*. The former resemble twigs; and the latter, leaves of

plants. In the walking sticks (which are common in America) the wings are small, and inconspicuous or wanting, and these insects mimic in coloring the plants on which they feed. The young insects, which appear usually in May, are green, but, as they grow older, change color with the foliage. The egg is seed-like in appearance. Our common form is wingless. The walking leaf is found generally in tropical countries.

4. Crickets have very long, curved antennæ, and large, rounded, vertical heads. The house cricket is not common in this country, being a native of the Old World.

5. The Katydid, which is the nearest relative of the grasshopper, makes its sound by rubbing the strong veins of the transparent basal part of one wing cover over those of the other. The call of the male is answered by the female in a shorter reply.

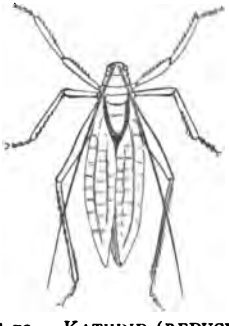

FIG. 72. — KATYDID (REDUCED).

The eggs of the katydid are usually laid, overlapping each other, along the stem of some plant which the female has previously roughened by biting. In some species the eggs are placed along the edge of a leaf.

6. The Migratory Locust. — The members of *Orthoptera* that have attracted greatest attention from mankind from earliest ages are the migratory locusts. From the time of Pharaoh down to the present day, this insect has been the dread of man. Just as crops are ready for the harvest, a cloud of these insects may appear darkening the sky. They fall upon the fields, and in a few hours these are barren and leafless. These insects have strong wings for flight, and large air sacs, which can be inflated at will, to diminish the relative weight of the body. Assisted by the wind, they traverse long distances,

FIG. 73. — ROCKY MOUNTAIN LOCUST.

often at a rate of twenty or thirty miles an hour. Meeting a cross current, they suddenly drop and pile upon each other, covering the ground inches deep. Many are killed by the fall. The rest immediately begin the work of devastation, and the sound of the multitude of moving jaws is compared to the crackling of a prairie fire.

The Agricultural Department of our government has made considerable effort to find the best means of fighting the Rocky Mountain locust, and several methods have been tried with more or less effect. It is hoped that before long the continued study of the subject will result in a successful plan of extermination.

General Characteristics. — Well-developed mandibles; fore wings thickened, straight, and narrow; hind, large, gauzy, folded in fan-like plaits (or wanting in a few cases); legs large and strong; antennæ well developed; metamorphosis incomplete.

HEMIPTERA, OR HALF-WINGED.

The Cicada. — Among the *bugs* occur the most disagreeable and disgusting forms known, yet there are a few interesting and valuable ones. Perhaps as well known a large form as any is that of the *cicada* or *harvest fly*, often incorrectly called a *locust*. This insect is the one whose shrill cry is often heard through the hot summer days.

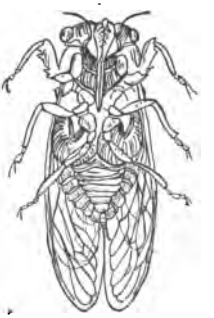

FIG. 74. — CICADA (UNDER SIDE).

It has a heavy body, wide, blunt head, prominent eyes, bristle-like antennæ, ocelli far back on the head. The mouth parts consist of a horny,

tapering tube (the modified labium), inclosing four bristles (modified mandibles and maxillæ); the latter for piercing, the former for sucking its fluid nourishment, the juice of plants. When not in use, this beak is held doubled under the body.

The fore wings of the cicada are elliptical, and longer than the body; are very peculiarly veined, being transparent, though strong. The hind wings are smaller and more membranous. The legs are short, the hind pair being spiny.

FIG. 75. — PUPA CASE OF THE HARVEST FLY, OR DOGDAY CICADA, CLINGING TO A TWIG.

According to some authorities, the sound made by this insect is produced in the following manner: In a cavity upon each side of the abdomen is a plaited membranous sac, which constitutes the vocal organ. When air is driven with force against the plaited edges, their vibrations produce an exceedingly shrill sound. This vocal organ is peculiar to the male cicada.

The general coloring of the common cicada is green and black, powdered with white below.

The female cicada has an ovipositor, by means of which she punctures a hole into the stem of some tender plant, and then forces her eggs some distance down into the opening. The larva hatches in about six weeks, and, dropping to the ground, buries itself in the soil, where it lives

upon the juices of the roots of forest or fruit trees, until more than a year and a half has passed. Then, having changed to a pupa, in the early summer it bores a hole to the surface of the ground, and appears, a clumsy-looking insect, brownish in color, and wingless. It crawls up some support, and grasps it tightly, till the pupa skin splits along the back, and the imago escapes. In a few hours the wings have dried, and the insect flies away. Its metamorphosis is incomplete, for there is no distinct quiet pupal stage. The cast-off pupa skins are common on fences, and trunks of trees.

Other Hemiptera. — Besides the common cicada, there is one form whose development takes seventeen years. In

FIG. 76. — SEVENTEEN-YEAR CICADA.

the *seventeen-year locust* the eggs are placed in the youngest twigs of deciduous trees. Its larval and pupal stages are also passed underground. There is a thirteen-year variety of this insect found in the Southern States.

Besides the cicadas, other well-known bugs are such parasitic forms as the *lice* of men and animals, *bedbugs*, *plant lice*, *bark lice*, *leaf hoppers*, the *chinch bug*, the *squash bug*, *skippers* or *skaters*, etc.

Notes. 1. **Plant Lice** abound everywhere on all parts of plants, sometimes doing great injury by their habit of sucking the

juices, causing leaves to shrivel, grain to shrink, and often killing the plant outright. Their enemies are the little lady beetles, and a tiny insect, an ichneumon fly (which will be described later on). The eggs of this are placed under the skin of the plant louse; and the larva, developing, feeds upon and kills the plant louse. Some species of plant lice give off a sweet excretion; and ants are so fond of this, that they will keep these plant lice like herds of cattle, that they may feed upon the sweet stuff.

2. **Bark Lice.** — A bark louse of India yields the lac which is the shellac of commerce. The female *Coccus lacca* punctures with her beak the twigs of the banyan or some other tree, and from the wound exudes the resin which is so valuable in making varnishes.

Various bark lice furnish red dyestuffs. The most notable, *cochineal*, is made from the dried bodies of females of the *Coccus cacti*. These feed upon the cactus, which is raised for the purpose of propagating the insect. The insects are carefully collected, and then killed by the use of heat, steam, or hot water; and it is calculated that seventy thousand are required to make one pound. The dye was in use among the native Mexicans at the time of the earliest Spanish invasion; and since that time Peru and Mexico, Algiers and Spain, all produce it.

The scale insects which infest orange, lemon, fig, olive, and apple orchards, all belong to this family, *Aphididæ*.

3. **The Squash Bug** (*Anasa tristes*) is very destructive to squash vines, sucking the sap from the stem near the ground. The young attack the leaves, and cause them to wither. They appear in June; and successive broods hatch till October, when these insects seek quarters in which to hibernate.

4. **The Chinch Bug** is the pest which in past years has done great damage to the wheat and corn crop. The insect is small, only three twentieths of an inch in length; yet the amount of injury done by the chinch bug in Illinois alone, in 1864, is estimated at over seventy-three million dollars.

5. **The Bedbug.** — The name "bug" was first given to one of the lowest and most repulsive of the order, — the *bedbug*. This

is wingless, as is its relative the louse. Both are hard to exterminate, and one essential to their annihilation is absolute cleanliness.

General Characteristics. — Bugs are all alike in having the mouth parts modified into a piercing, sucking beak. Some of them are wingless. In others the fore wings are divided into two distinct regions, — a thickened base and a membranous outer portion. The latter characteristic, common to many bugs, gives the name *Hemiptera* (*half-winged*) to the order. Many bugs secrete a fluid having a disagreeable odor, probably for their protection.

DIPTERA, OR TWO-WINGED.

The House Fly. — In the order *Diptera* are included a number of well-known insects, among which are flies, fleas, and mosquitoes. The common *house fly* (*Musca domestica*) is a good example for study, being found over almost all the known world.

The body consists of head, thorax, and abdomen, distinct from each other. The head is large, and is joined to the thorax by a slender neck. The mesothorax is very large in proportion to the other thoracic segments. The abdomen is short, containing from five to nine segments, including the joints of the ovipositor. The legs are not very strong, but the feet are each armed with two claws, between which are two membranous pads. These pads are covered with tubular hairs that secrete an adhesive fluid, and by this means the foot clings to smooth surfaces. The claws enable it to hold to roughened surfaces. Thus the foot is so modified that the fly can walk upside down with ease.

The wings of the fly are only two in number, and are attached to the mesothorax. They are transparent, and are moved in flight from three to four hundred times per

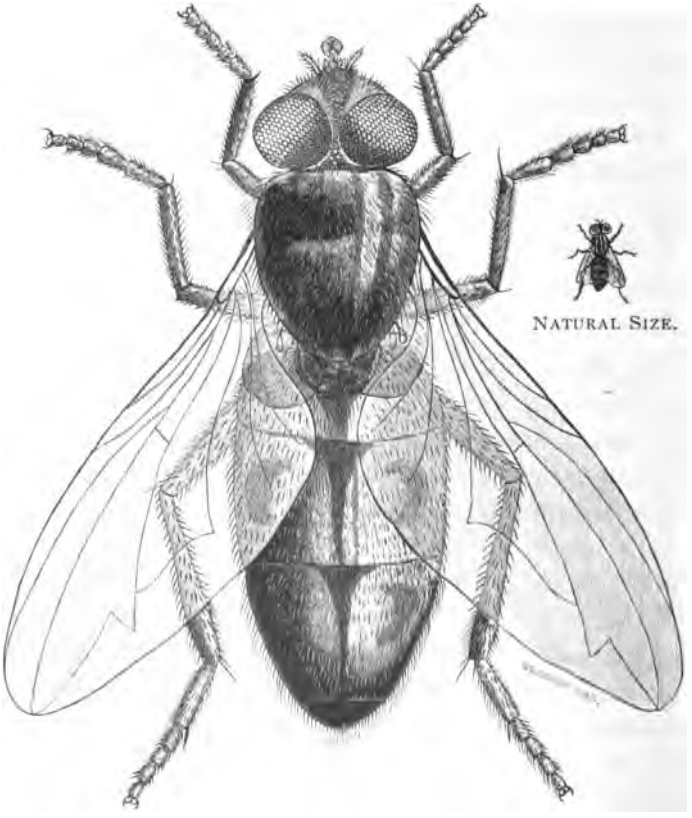

FIG. 77. — FLY (MAGNIFIED).

second, describing in the air the form of the figure 8. Just behind the wings are two little membranes called *winglets*, which open and close with the motion of the

wings. On the metathorax is a pair of organs called *balancers*, which are supposed to be modifications of the hind wings, being constantly vibrated during flight. Each consists of a slender thread knobbed on the end. The function of these organs is not known. They are by some believed to be organs of hearing; by others, to be concerned in respiration.

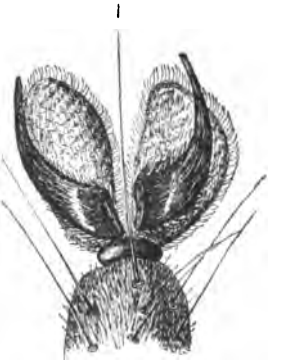

FIG. 78. — FLY'S FOOT (MAGNIFIED).

The antennæ of the house fly are three-jointed, and each is terminated with a feathery bristle. The compound eyes are large, consisting of about eight thousand hexagonal facets. The three ocelli are above the compound eyes and antennæ.

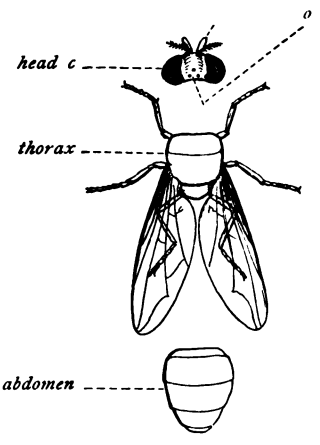

FIG. 79. — Head of fly having mouth parts, antennæ, compound eyes (*c*) and ocelli (*o*); thorax, having legs and wings; abdomen, never having legs or wings.

The mouth parts of the fly furnish another remarkable example of the way in which the organs of all animals are adapted to their use. The mouth consists of a proboscis, which is bent under the body when not in use. The maxillæ, maxillary palpi, and mandibles are all small, and of little if any use. The fleshy labium acts as a tongue.

When unbent and extended, the broad, knob-like end divides into two flat, muscular organs called *labellæ*. These are roughened upon the surfaces thus exposed, and act as a rasp in scraping or tearing delicate surfaces; and it is by means of these labellæ that the fly annoys us as it licks the perspiration from the skin in warm weather. By means of this tongue-like organ the fly takes up the liquid sweets of which it is so fond.

FIG. 80.—AN INSECT WITH TWO WINGS.

The digestive apparatus of the fly is rather simple, since it takes mostly liquid food, or that softened by saliva. Lying in a channel in the upper surface of the labium is a sucking tube. This conveys the food to the esophagus. The food is sucked in by means of a sucking stomach or crop which connects with the esophagus. Beyond this, the digestive apparatus is simple and rather tubular.

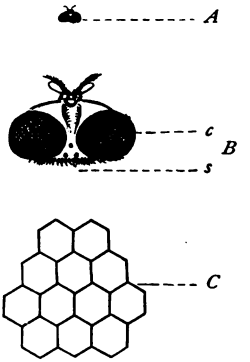

FIG. 81.—HEAD OF FLY, SHOWING COMPOUND AND SIMPLE EYES: *A*, head of fly, natural size; *B*, head of fly, enlarged eight times; *c*, compound eye; *s*, simple eyes; *C*, portion of the surface of a compound eye, highly magnified.

The house fly breathes by means of two main tracheæ, which connect not only with branches, but also with two abdominal air sacs.

The nervous centers are confined chiefly to the head and thorax. Touch is located mainly in the antennæ.

The organ of smell has not been located, but it is evident that all flies have it.

The humming of the fly, as of the bee and other insects, is produced by the motion of the wings; and one scientist, having carefully investigated the subject, assures us that it varies in pitch as the insect wishes to express different emotions, being thus a true language. Another scientist asserts that flies produce a low tone by the vibration of the wings, but that a higher tone is produced by the thoracic stigmata, and is therefore the true voice of the insect.

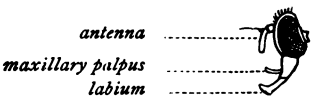

FIG. 82. — HEAD OF HOUSE FLY, SHOWING MOUTH PARTS.

The development of the house fly is as follows: The eggs are laid about barns or stables, or in filth of any kind, and are hatched in twenty-four hours. The larvæ, called *maggots*, are fleshy, yellowish white, and footless. They feed for fourteen days. Then they pass into the pupa state. The pupa case is brownish and seed-like. After a period of from one to two weeks has expired, the imago appears. This generally lives but a single summer; only a few flies, when cold weather approaches, hiding themselves in protected places, and so hibernating.

House flies are troublesome creatures, and various devices are used to kill them off or to shut them out of houses; yet on the whole they are very beneficial to man, acting as scavengers, and devouring substances whose decay would otherwise breed disease.

The Mosquito. — Another well-known insect among the *Diptera* is that very annoying one, the *mosquito*. Much

more slender and graceful than any other of the order, the beauty of its form might be admired, were it not for the recollection of uncomfortable attacks from its bill. The

FIG. 83. — METAMORPHOSIS OF MOSQUITO: EGGS, LARVA, LATER STAGE ON THE RAFT, AND ADULT.

head is round, with two large compound eyes. The antennæ are long and slender. The legs are also longer and more slender than those of the fly. The wings are fringed with silky hairs.

But it is the curious development of the mouth parts that is most interesting. The long bill is really a set of piercing instruments by means of which the female mosquito (for it is she alone who haunts our houses and annoys us) punctures the skin and sucks the blood of her victim. The labrum and labium together form a sheath, inclosing the other mouth parts when they are not in use.

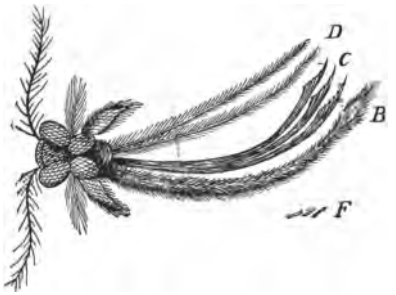

FIG. 84. — BILL OF MOSQUITO, SHEATH OPEN: *B*, the sheath; *C*, three lancets; *D*, protectors; *F*, above parts, natural size.

For this purpose the fleshy labium is channeled on its upper side; the labrum, upon the under. Within this sheath are the mandibles and maxillæ, which are slender and bristle-like. In addition to these, there is a slender unpaired organ (the *hypopharynx*), tubular, for the passage of the saliva, the outlet being near the tip. The hypopharynx lies in such a position, that between it and the labrum is a canal through which the food passes. When the mosquito is biting or feeding, these mouth parts, except the labium, are held close together.

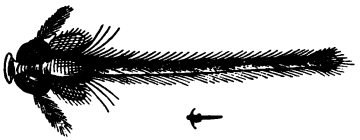

FIG. 85. — BILL OF MOSQUITO, SHEATH CLOSED (NATURAL SIZE, AND MAGNIFIED).

By some it is believed that the saliva of the mosquito is projected into the wound, and poisons it; by others, that the puncture is sufficient in itself to cause the irritation.

By some it is also believed that the singing of the mosquito aids her in obtaining a full meal; for the nervous irritation caused thereby causes an increased blood flow in the superficial blood vessels of her intended victim, these vessels become fuller, and so she accomplishes her purpose more easily.

The male mosquito does not bite, seeks shelter in the woods, and only lives a short time.

The life history of a mosquito is full of interest, and varied. A boat-shaped mass of eggs is laid in the water. In a few days they hatch, and the larvæ, called *wigglers*, escape. Each little larva wriggles about in the water, being active as a scavenger. When at rest, it is near the surface of the water, head downwards. During this stage it breathes by tracheæ, which receive their air supply through a single tube at the end of the abdomen. This is thrust out of the water for the purpose. After changing its skin two or three times, the head and thorax become heavier, the tracheæ open through two tubes on the thorax, and the abdomen is terminated by two leaf-like appendages that propel the insect, now a pupa, about. In a few more days the pupa skin bursts, and the perfect insect emerges, using this cast-off skin as a raft upon which to rest until the wings dry and spread, and it is able to fly away. It is just at this point that many mosquitoes lose their lives; for the frail raft is upset by the slightest disturbance, and its freight dropped into the water. Mosquitoes, therefore, never develop in running water.

The Flea. — Still another familiar insect among the *Diptera* is the *flea*. This is somewhat different from the fly and mosquito, in having a short, compressed body, in

being wingless (though in some species wing pads are noticed), and in having the three thoracic segments equal.

The legs are long and strong, especially the hind pair, so that the flea can leap from 200 to 300 times its own height. Imagine a man endowed with equal powers!

The flea has no compound and only two simple eyes. The labrum is wanting, and the labium not well developed; but the other mouth parts are fitted for piercing and sucking.

The eggs of the flea are laid in the fur or hair of its victim. They drop to the ground, and in six days are hatched, the long cylindrical larva living two weeks upon decaying animal or vegetable matter. Then the insect either spins a rude cocoon, or, according to one authority, is merely inclosed in a pupa case. The pupal stage lasts from ten days to two weeks.

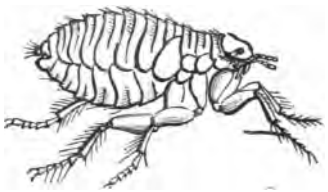

FIG. 86. — HUMAN FLEA (MAGNIFIED).

To rid animals of these pests several remedies are proposed, — the use of a good insect powder, washing the afflicted animal in strong soapsuds, or rubbing with coal oil. The kennels of dogs should be frequently cleaned, bedding changed, etc.

Notes. 1. **Growth of Insects.** — Many people erroneously suppose that insects grow in the imago state; for instance, that the tiny flies occasionally seen about houses are young house flies. They are full-grown flies of smaller species. The principal growth of an insect is during its larval stage.

2. The Horsefly (*gadfly* or *breeze fly*) is in its larval stage, like many other insects, beneficial in destroying refuse matter; but in its imago form it is a very dangerous enemy of horses and cattle. Its jaws are lancet-like, and a swarm of horseflies has been known to kill these animals. As in the case of the mosquito, it is only the female that is troublesome, the male living upon honey. These flies are never about in cloudy weather, and the first frost kills them.

3. The Botfly. — Another very curious fly is the *botfly*, whose larva lives under the skin of different quadrupeds, causing painful tumors. After a month or two it emerges, drops to the ground, and buries itself, to go through the pupal stage. The larva is a thick, fleshy, whitish, footless creature, whose segments are covered with rows of tubercles. The pupa retains the larva skin for its protection.

4. The Hessian Fly, so destructive to wheat crops, is a small gnat about an eighth of an inch long, whose eggs are deposited in the folds of the young blades soon after the grain begins to grow. They hatch, and the larva crawls down the leaf until it reaches the joint between the leaf and the stalk. Here it remains, nourished by the sap of the plant. As it grows, its body becomes imbedded in the stalk. When several larvæ attack one stalk, it becomes so impoverished that either the grain is not filled out, or the whole plant perishes.

5. Protection of Food. — There are numerous instances on record in which human beings have suffered from violent illnesses caused by larvæ of flies which have been introduced into the stomach with food upon which the larvæ have been feeding. Too great care cannot be taken to protect food of all kinds from these insects.

6. The Crane Flies are large flies, that, from their long, slender bodies and legs, have often been incorrectly called "giant mosquitoes." They are harmless except in their larval stage, when they often prove quite destructive in grass lands.

7. Fleas. — The most recent classification places fleas in a separate order (*Aphaniptera*), since they differ in many respects

from the true flies, and bear some relationship to the *Hemiptera* and *Orthoptera*.

General Characteristics. — Mouth usually adapted for piercing and sucking; generally one pair of wings developed, the second being modified into a pair of balancers; metamorphosis complete.

LEPIDOPTERA, OR SCALY-WINGED.

In the order *Lepidoptera* are included the *butterflies*, *moths*, and *hawk moths*.

Butterflies. — A large and showy butterfly, common through the East, is *Papilio turnus*. The wings, which

FIG. 87. — PAPILIO TURNUS, LINN.

are the chief means for the identification of the insect, are yellow banded with black, a row of yellow spots marking the marginal bands. The fore wings are nearly triangular,

and expand from four inches and a half to five inches. The hind wings are tailed. The wings are covered with a fine dust, which, examined under the microscope, is seen to consist of little, overlapping, feathery scales, fastened into the skin by short stems. When at rest, the wings are raised and laid back to back.

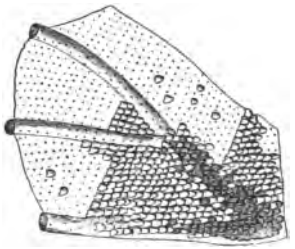

FIG. 88. — SCALES ON THE WING OF A BUTTERFLY.

The legs are long. There is a spur just above each tarsus or foot, and the latter is armed with two claws, the butterfly's legs not being used much for locomotion, but rather for grasping.

The head is comparatively small. The compound eyes are large and round. The antennæ are knobbed on the end, and are organs of smell. The abdomen is oval, and not very large.

The mouth parts are developed for sucking. Labium, labrum, mandibles, labial and maxillary palpi, are either wanting or small; but the maxillæ are long, and grooved on their opposed sides, forming a tube through which sweets are sucked. This sucking tube (called the tongue), when not in use, is coiled like a watch spring, and held under the head.

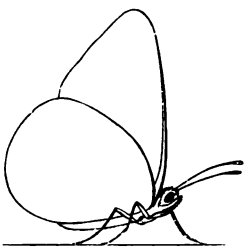

FIG. 89. — BUTTERFLY AT REST, WITH WINGS MEETING OVER THE BACK.

The digestive apparatus in the imago is adapted to the

digestion of liquid food. Honey is drawn through the tongue by means of a sucking stomach connected with the esophagus. This sucking stomach consists of a tube to whose upper and lower surfaces muscles are attached, that by their contraction enlarge the tube, thus drawing in whatever is in the esophagus, and by this pumping motion forcing it on into the intestine.

The eggs of *Papilio turnus* are laid upon the apple, cherry, sassafras, willow, etc.; and when hatched, the young larva begins to feed at once upon leaves of the tree on which the parent, by wise instinct, placed the egg. As the caterpillar grows rapidly, it molts several times, and with each molt the color and markings alter. When fully grown, it measures from two inches to two inches and a half in length, and is of a green color above, spotted with small blue dots. A pair of yellow eye spots with black centers is near the head. The head is brown. The legs and under part of the body are pale green. The legs of this caterpillar number eight pairs, — one pair to each of the first three segments behind the head, four more pairs on successive abdominal segments, and one pair at the end of the abdomen. This larva, when disturbed, thrusts from a slit in the fore part of the body a pair of soft orange-colored horns, like the letter Y in shape, called *osmateria.* These give out a strong, disagreeable odor, probably intended to defend the caterpillar from the attacks of its enemies. The larva is also provided with silk glands, — two long sacs, one on each side of the body, but opening together on the labium.

FIG. 90. — CATERPILLAR OF PAPILIO.

About the first of August the caterpillar prepares to become a chrysalis. It seeks some sheltered spot, and, selecting a perpendicular support, upon the upright surface it spins a little tuft of silk, and in this entangles the hind feet. Then it proceeds to make a loop of silken threads, the ends being so fastened to the support as to form a girth about the middle of the body; and so suspended, with head up and back away from the support, it casts off its caterpillar skin, and becomes a chrysalis. In this condition it bears little resemblance to the previous form. Upon close examination, however, faint resemblances to the imago may be seen in traces of head, tongue, antennæ, wings, and legs, pressed against the body. While a chrysalis, the insect is apparently lifeless. It remains a chrysalis through the winter, and it is not until June that the final transformation takes place. Then the pupa case bursts along the back, and from the rent issues the butterfly. Its body is at first weak, the wings small and crumpled. Soon, however, the wings spread to their full dimensions, the body dries, the legs become firm, and the insect is ready for flight.

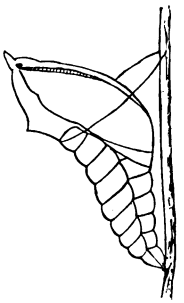

FIG. 91. — BOUND CHRYSALIS.

In the South and West, closely related forms are found which will serve equally well to illustrate the structure and life history of the butterfly.

Moths. — Among the moths, one of the largest and

also one of the most interesting is *Telea polyphemus*. Its specific name was probably given it on account of its great size, the fore wings spreading from five to six

FIG. 92. — AMERICAN SILKWORM MOTH, OR POLYPHEMUS.

inches. The body of this moth is heavy and densely hairy. The head is small. The antennæ are not knobbed, as in a butterfly, but instead are feathered their whole length. The tongue and palpi are short and hidden. The wings are ocher yellow (sometimes inclining to fawn or mouse color), with black and white shadings and markings; on each wing a transparent eye-like spot. The hind wings are not tailed. When at rest, the wings are spread.

FIG. 93. — LARVA OF POLYPHEMUS.

During the early summer, the eggs of *Polyphemus* are laid on the under side of leaves of the oak or elm, a

single female producing between two and three hundred. In about twelve days the caterpillar appears. This molts several times. When fully grown, it is over three inches in length, a thick, fleshy, green worm striped upon the sides with pale yellow, and having bristly tubercles upon each segment.

In the latter part of September it begins to form its cocoon, which is completed in a few days. This is whitish, oval, and quite symmetrical, and inclosed within one or two leaves. As the cocoon is closed at both ends, the thread is continuous, and, having a strong and glossy texture, it might well be utilized, especially as the insect is hardy, and will bear confinement well. The pupa state continues through the winter. When the fully developed moth is ready to leave the cocoon, it discharges a quantity of fluid, which softens the silk at one end, and allows it to escape. In a few hours the wings have spread and dried.

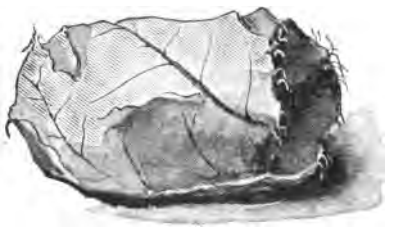

FIG. 94. — COCOON OF POLYPHEMUS, WRAPPED IN A LEAF.

If the pupa of *Polyphemus*, or any other moth, be kept in too warm a place, it develops too rapidly, and the wings of the imago will be small and imperfect.

The Hawk Moth. — Another moth, very well known both as larva and imago, is the *five-spotted sphinx*, or *hawk moth*, *S. quinquemaculata*. This is the common *humming-bird moth*, which, in flying, makes with its wings a sound similar to that made by a humming bird.

Its wings are long, narrow, and pointed, and spread about

FIG. 95. — THE HAWK MOTH.

five inches, being gray banded with black. When resting, the wings are folded roof-like over the body. The heavy body has on each side five orange-colored spots. The antennæ are long, thickest at the center, and hooked at the end. The tongue is very long (five or six inches), so that when it is uncoiled the insect can, while on the wing, obtain honey from very deep flowers.

FIG. 96. — HEAD OF HAWK MOTH, SHOWING COILED TONGUE, AND POLLEN MASSES, THAT HAVE BEEN TAKEN FROM SOME FLOWER, ATTACHED TO THE EYES.

The larva of this sphinx is the *potato worm*, feeding both on the potato and the tomato. It is a large green worm, with oblique white stripes upon the sides of the body, and with a horn upon the tail. It is very destructive to the vegetables or plants upon which it feeds. At the end of summer it crawls down the plant, and buries itself in the ground, there to spend the winter in the pupa state. As a chrysalis, it is of a bright brown color; and it has a long, slender tongue case, so bent as to bring the tip against the breast of the pupa, and looking something like the handle of a pitcher. In the early summer, the chrysalis skin bursts, and the moth comes out of the ground, mounts some plant, and, when evening comes, flies away.

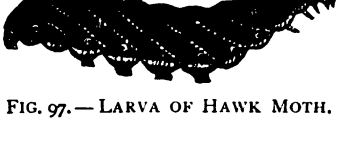

FIG. 97. — LARVA OF HAWK MOTH.

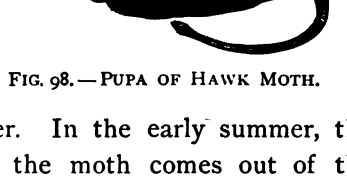

FIG. 98. — PUPA OF HAWK MOTH.

Notes. 1. **Pupa and Chrysalis.** — The term *pupa*, from the Latin ("doll" or "baby"), is supposed to have originated from the fact that the insect in this stage of its existence somewhat resembles an infant in swaddling clothes. The term *chrysalis*, from the Greek ("golden"), probably came from the fact that this form in many butterflies is marked and spotted with golden yellow. In the *Lepidoptera*, the term *pupa* is usually applied to the moth, which incloses itself in a cocoon, while *chrysalis* applies to the same stage in the butterfly.

2. **Moths and Butterflies.** — While the imago forms of many moths and butterflies attract us by their beauty, and while as

imagoes they assist considerably in the fertilization of plants by carrying pollen, the larvæ of these insects are in most cases very

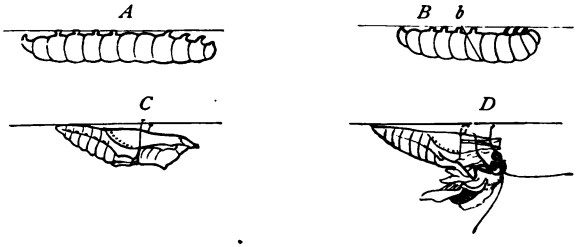

FIG. 99. — *A*, caterpillar getting ready to change into a chrysalis; *B*, just ready to shed its skin previous to changing; *b*, little band to hold it up; *C*, chrysalis; *D*, butterfly just escaping from chrysalis, the wings just being unfolded.

destructive, devouring the leaves of shade and fruit trees, garden vegetables, fruits, grains, etc. In a single year the amount of damage done by these insects is enormous. The little white cabbage butterfly (*Pieris rapæ*), which was introduced into this country from Europe about the year 1860, was estimated to destroy annually, not many years thereafter, just around Quebec, two hundred and forty thousand dollars' worth of cabbages. The army worm and the cotton worm, etc., are equally destructive.

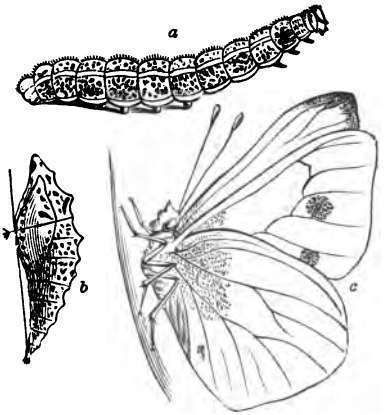

FIG. 100. — LARGE WHITE CABBAGE BUTTERFLY (PIERIS BRASSICÆ) OF EUROPE: *a*, larva or caterpillar; *b*, pupa or chrysalis; *c*, imago or perfect insect.

3. The Apple Worm. — An insect well known in its larval stage is the *apple worm* (*Carpocapsa pomonella*). The egg is laid upon the eye or blossom end of the apple, where the skin is tender. The little worm burrows into the fruit to the core. It develops during

several weeks, eating its way about in the apple. To get rid of the refuse fragments of its food, it bores a channel through the side of the fruit, and disposes of them through the opening. When the apple falls, which it generally does before it would if it were not so infested, the worm escapes through this side opening. The moth is small, with brown wings, the fore wings the darker. To rid orchards of this pest, which attacks both apples and pears, the trees should be sprayed with Paris green and water, just after the blossoms have fallen; and all wind-fallen fruit should be daily gathered, and disposed of in such a way as to kill the worms.

4. The Clothes Moth. — The little *clothes moth* (*Tinea pellionella*, Linn.), whose wings do not spread over half an inch, is either silvery gray or fawn colored. It deposits its eggs in wool, fur, feathers, hair, and on insect collections. The larva appears in about a week, begins to feed, and constructs a portable cylindrical case out of the material on which it is feeding, leaving it open at both ends, and lining it with silk. As the worm grows, it enlarges its case by splitting it and inserting a gore, first at one end and then at the other. It thrusts its head out to feed, and moves about, carrying the case with it. All the transformations from larva to pupa and to imago occur within this case. The best precaution to be taken against this destructive little creature is frequently to shake and beat garments and carpets. Clothing to be packed away should be well aired and shaken, and then sealed up in heavy paper bags. The use of tobacco, camphor, or tar balls or paper, is recommended. Cedar chests are good places in which to store garments, blankets, etc.

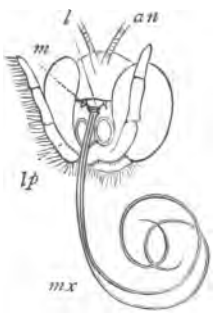

FIG. 101. — MOUTH OF LITTLE WHITE CABBAGE BUTTERFLY (ENLARGED): *l*, labrum; *m*, mandible; *mx*, maxilla; *lp*, labial palpus; *an*, base of one of the antennæ.

General Characteristics. — Wings covered with overlapping feathery scales; mouth parts, a coiled, tubular tongue for sucking; larva, a caterpillar; metamorphosis complete. Butterflies, hawk moths, and moths differ in the character of the antennæ, in the length of the tongue, in the shape of the head and body, in the position of the wings when at rest, in their different pupal conditions, and in the fact that butterflies usually are day flyers, while moths generally fly at night.

HYMENOPTERA, OR MEMBRANE-WINGED.

The order of *Hymenoptera* includes *bees*, *wasps*, *ants*, *saw flies*, *gall flies*, and *ichneumon flies*. Ants and bees, from their social habits and from their superior intelligence, are perhaps, of all the insects, the most interesting objects of study.

FIG. 102. — QUEEN OF SLAVE-MAKING ANTS (MAGNIFIED).

Ants. — A common *red ant* (*Formica sanguinea*), occurring in Europe and America, will serve to illustrate the characteristics of the family. The body is distinctly divided into head, thorax, and abdomen. The head is large, with large, compound eyes and three ocelli. The antennæ are long and slender, and are supposed to be the seat of both smell and hearing. The wings, in those forms that are winged, are thin and mem-

branous, and with few veins; yet they are powerful organs of flight. The mouth parts are, like those of the beetle, adapted for biting, the labium being prolonged to form a *ligula* (or tongue) for lapping liquid sweets. The food of ants consists of insects, honey, or fruits. There is scarcely any animal or sweet stuff which they will not devour. The digestive apparatus resembles that of the beetle.

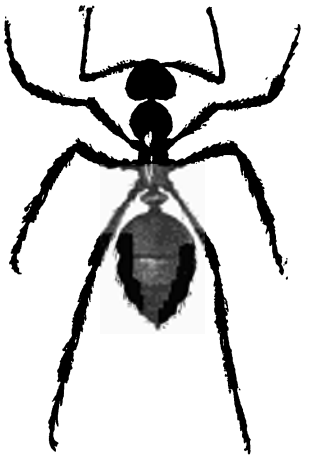

FIG. 103.—SLAVE-MAKING ANT (MAGNIFIED).

The abdomen in some ants is armed with a *sting* in the female. The poison which supplies this comes from two glands in the abdomen. In *Formica sanguinea* the sting is not developed, probably from disuse, but the poison glands are large.

In the colony of *Formica sanguinea* the number of individuals is very great. There are three kinds, — *winged males*, *winged females* or *queens*, and *wingless workers*. The queens are the largest, and there is usually one; but often sev-

FIG. 104.—ANT NEST, WITH UNDERGROUND PASSAGES.

eral queens live harmoniously in the same nest. The workers are the smallest forms, but they are far the most numerous.

The nest of this ant consists of a hillock of sand or clay, divided into compartments. Leading from the nest are well-constructed roads and covered galleries, as well as tunnels.

The life of an ant consists of four well-marked periods. The queen ant (or winged female), after her marriage flight, returns to the nest, and tearing off her wings, for which she has no further use, retires to her cell.

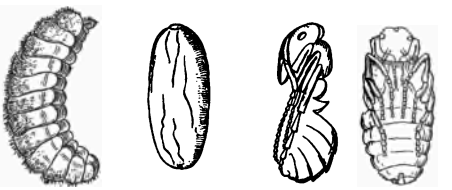

FIG. 105. — LARVA, COCOON, AND PUPÆ OF RED ANT (MAGNIFIED).

Here the eggs are laid. They are said to hatch in about fifteen days. The larvæ are small, legless grubs. They are fed and tended by the young workers, being carried about from chamber to chamber to get the proper amount of warmth, air, and moisture. During this period they grow rapidly. When they turn into pupæ, each is surrounded with a silken cocoon, and is often in this condition called an "ant's egg." These "ant's eggs" are also aired and sunned by the workers. When the young imago is ready to emerge from the pupa case, it is often assisted by the older ants, which carefully unfold its legs, and spread out its wings.

The ants in a colony of *Formica sanguinea* sometimes sally forth, an army in battle array, for the purpose, it would seem, of capturing slaves. The colony attacked is usually that of a timid little black ant (*Formica fusca*). The attacking ants seem to wish rather to terrify than to kill; and they merely drive out the black ants from their nest, capturing and carrying off the eggs, larvæ, and pupæ of the defeated colony. These are cared for and carefully reared, to become slaves to their captors, by whom, however, they are kindly treated and protected.

Ants are able to recognize their friends, even after a separation of several months. Experiments have been made to determine the amount of intelligence possessed by them. The results of these would indicate that with ants as with men, the amount of intelligence varies with races and also with individuals; but their social organization and their habits show that they possess something more than mere instinct.

Whether they possess any vocal powers is a subject for investigation. Although they possess an organ which, from its structure, seems to be an ear, they are apparently undisturbed by ordinary sounds. They have, however, organs resembling the sound-producing organs of other insects. These produce no sounds audible to us, but that is no proof that they do not produce tones beyond the limits of our hearing, but which are audible to them; and the results of many experiments prove conclusively that they possess some means of communication equivalent to a language.

Notes. 1. **Age.** — It has been until recently the general opinion, that the life of an ant is of short duration, that only the

workers hibernated, and that none lived more than a year. Sir John Lubbock states, however, that he had two queens that lived over seven years, and workers that lived, to his knowledge, over six years. The males are probably short-lived.

2. **Color Perception.** — Sir John Lubbock, by a series of very pretty experiments, proved that ants are not only capable of distinguishing between the colors which we perceive, but that the chemical or heat rays — dark to us — evidently appear to them as other colors.

3. **Honey Ants.** — One or two curious species of ants have in their colonies individuals which seem to be animated honey jars. The abdomen becomes much distended, and is filled with honey collected by other ants. The sole function of these ants seems to be to store and redistribute the sweet.

4. **The Agricultural Ant.** — It is well known that in the warmer parts of the Old World, and also of our own country, certain species of ants are farmers. The *agricultural ant* of Texas clears a field ten or twelve feet square around the entrance to the nest. Nothing is allowed to grow upon this but a certain grass, whose seed is carefully harvested and stored up for use. The nest consists of both underground and overground compartments. During the rainy season, eggs, larvæ, pupæ, and food are removed to the upper structure out of the reach of the water, which must flood the chambers underground. During the heat of the dry season, they occupy the underground chambers.

5. **Slave-making Ants.** — Among the *slave-making ants* some species become so dependent upon their slaves, that, when left without, they are utterly helpless. They show no care for their young, take no part in providing supplies, are not even able to clean or feed themselves. Not only are their habits materially changed by this dependence, but even the structure of their bodies. The mandibles lose their teeth, becoming weapons of warfare, but useless as organs of mastication; so that if not fed by their slaves, these ants must die of starvation.

6. **Domestication of the Aphis.** — Some of the ants domesticate another insect, the *aphis* or *plant louse*, on account of a sweetish

secretion given off from the body of the latter. This secretion is generally retained until the ants are ready to receive it. An ant strokes the aphis with its antennæ, when the secretion is emitted. Not only do the ants protect and care for the full-grown aphides, but they collect their eggs and guard them, rearing the young in their nests, and in the spring bringing them out and placing them upon the proper plants. Besides the aphis, various other insects are utilized in a similar manner by ants; and not only are they domesticated on account of utility, but in some instances it is believed to be solely as pets!

7. **Games and Sports.** — It has been noticed by reliable observers that ants sometimes engage in games and athletic sports with as much ardor as human beings could show.

8. **Development.** — Sir John Lubbock calls attention to the fact that among the different species of ants, the differing habits and conditions may remind us of the earlier stages of human progress and civilization. There are those which live only upon the product of the chase, resembling those lowest races of men who subsist mainly by hunting. Like them they live in comparatively small communities, and have but little organization. Then there are those whose homes are constructed more carefully, whose communities are larger, which have domesticated animals, and who have much more organization in both labor and warfare, enslaving or exterminating those weaker and less well organized communities. Lastly come the agricultural ants. There is a curious analogy in this to the three great stages in the history of human development, — the hunting, the pastoral, and the agricultural.

Bees. — The *bees* are next to the ants in interest. The *honey bee* resembles the ant in structure, except that the body is hairy, and that upon the legs of the workers are "honey baskets," in which pollen may be carried. Each hind tibia, and the basal joints of each hind tarsus, is enlarged. The tibia is hollowed on the outside; and stiff bristles project over the cavity, from either side of the joint.

The pollen is conveyed from the mandibles to this hollow by a rapid movement of the other legs.

Bees gather three different materials, — *nectar* (or honey), *pollen* (the dust from the stamens of flowers), and *propolis* (or *bee glue*). The latter is a red, resinous substance, somewhat like wax, and collected from the viscid buds of various trees. This is used to stop crevices in the hive, and also to help cement the wax of the cells together. Like the pollen, it is carried in the honey basket. The honey, or nectar, is collected from flowers by the long tongue, which laps it up, and it is passed through the esophagus into the crop. Here it is carried. It undergoes some chemical change in the crop, and is then regurgitated into the honey cells of the comb. The change which it undergoes renders it incapable of fermentation.

QUEEN. DRONE. WORKER.

FIG. 106.

The wax of which the comb is constructed is a secretion from the body, which collects in little scales on the under surface of the abdomen, is removed by the legs to the mouth, where it is softened, and prepared for the construction of the comb.

Among the bees, as among the ants, there are three kinds of individuals, — *queens*, *workers*, and *males* or *drones*. The queen is the largest, and has a more slen-

der abdomen than either drone or worker. The latter is the smallest. Every queen and worker is supplied with a sting upon the end of the abdomen. The drones are stingless; and as the queen only uses her sting upon another queen, the worker is the only one from whom a human being need fear injury. When a bee uses its sting, it is generally left in the wound. The loss of its sting is a mortal injury to the bee, who, however, suffers no pain, and lives some little time afterwards.

FIG. 107. — A BEE'S STING: *d*, dart magnified.

A worker gathering honey or pollen flies from flower to flower, and has been known to go several miles from home in search of supplies. When it has all it can carry, it starts for its hive, and so true is its sense of direction, that it never varies from its straight course: hence the expression, "bee line."

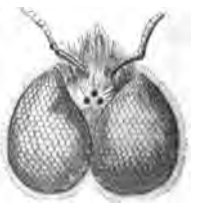

FIG. 108. — HEAD OF A BEE, SHOWING COMPOUND EYES, SIMPLE EYES, AND ANTENNÆ.

The comb usually contains cells for the development of the young, and also those for the storage of honey and pollen. These cells are irregularly hexagonal, and not only vary in mathematical precision, but also in size. Among the larvæ cells, those intended for the workers are small-

est, the drone cells next in size, and the queen cells the largest. Honey cells are more regular, and when filled are sealed up to exclude the air.

The history of a hive of bees is as follows: A queen, which, with a few workers, has lived through the winter, lays its eggs, first in the worker and afterwards in the drone cells. Early in the summer, larger cells are built on the edge of the comb, and in these, according to the best authorities, the queen larvæ are placed, and fed with rich and choice food. It is believed that the eggs which produce queens and workers are alike, the difference in the mature insects being due to the difference in the conditions under which the larvæ are developed. The eggs which produce drones are unlike the others. It is said that workers sometimes lay eggs, and that these always produce drones. The eggs are placed by the queen, one in each cell. These are hatched in a few days; and the young larvæ, which lie doubled up in the bottoms of the cells, are fed by the workers on a mixture of pollen, honey, and water. A substance called "royal jelly," supposed to be more stimulating, is fed to the queen larva. In a few days

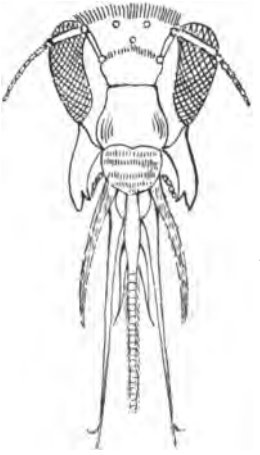

FIG. 109.— FRONT VIEW OF THE HEAD OF A BEE.

more the larvæ cease feeding, spin silken cocoons, and become pupæ, their cells being then closed by the workers. Three weeks after the egg was laid, the winged insect appears. In the case of workers and drones, this at once escapes from its cell; but the young queen is not released immediately, but is still confined, being fed by the workers. At last, however, a young queen comes forth from her cell. The old queen then deserts the hive, carrying away a part of its inmates, and leaving the new queen in full possession. Several queens are usually produced in a single hive in one season. At the appearance of each one, the preceding queen deserts the hive, with numerous followers. After the last queen has left her cell, the workers fall upon the drones, of which there are comparatively few, and destroy them without mercy. It is supposed that the workers never live longer than eight months, the first brood possibly only a few weeks; but queens are thought to have lived five years.

Notes. 1. **The Bumblebee.** — Among the bees, our common *humble* or *bumble bee* (*Bombus*) is very well known. Its nest is usually within a stump, a hollow log, in the ground, or in the burrow of some animal. The queen, who alone has survived the winter, collects a mass of pollen and honey, and in this deposits a number of eggs. After the eggs for one brood are laid, she collects more pollen, and lays the eggs for a second. As soon as the larvæ appear, they feed upon the pollen, rapidly attain their full size, and then each spins a silken cocoon, which is covered by the old bee with a layer of wax, thus being converted into a rude cell. When the imago is fully developed, it cuts its way out. After the first brood of workers appears, the queen resigns to them the duty of collecting food, building cells, etc.

2. **Solitary and Parasitic Bees.** — While many species of bees

are social in their habits, there are solitary ones whose nests are mere burrows in the ground. The bee uses her mandibles in digging, and shovels the dirt out with her feet. Such a nest is tubular, and has connecting with it several small cells in each of which are deposited a pollen mass and an egg. The larva feeds upon the pollen thus provided. A still lower form of bee is parasitic, laying its eggs in the cells built by other bees.

3. **Other Bees.** — There are other kinds of bees, whose nest-building habits have gained them the names *carpenter bee*, *tailor bee*, *mason bee*, etc. Among wasps, in the same way, we have *mud dauber*, *sand wasp*, etc.

Ichneumon Flies. — Differing greatly in habit and somewhat in structure from the preceding *Hymenoptera* are the *ichneumon flies*. One of the most common of these insects has a long, slender body, and instead of a sting it possesses a long ovipositor, by means of which its eggs are placed beneath the skin of the larva of the *Polyphemus* moth. The ichneumon eggs hatch, and the larvæ feed upon the supply of fat which they find ready for them. Often the ichneumon larvæ have not finished feeding when the larval moth spins its cocoon and transforms into a pupa. When the ichneumon larvæ are ready for the change to the pupa state, they leave the interior of the body of their victim, and attach themselves without, spinning their silken cocoons, and going through all their transformations, within the cocoon of the moth. Of course, the pupa *Polyphemus* dies before its transformation has progressed very far, and the ichneumon flies in due time issue from the cocoon instead.

Notes. 1. **The Hornet.** — Another insect whose habits are social, like those of the ants and bees, is a paper wasp, the *hornet*. The nest of this insect is of a papery substance, which the insect

manufactures by masticating weathered wood. The nest contains many hexagonal cells arranged in tiers or galleries, and protected without by a thick, papery covering of many layers. The nest is so hung that the cells open downward. It is said that the larva is probably held into its cell by a glutinous secretion. Hornets are omnivorous. Not only do they devour sweets, fruit, vegetables, meat, etc., but they fiercely attack other insects, using for this purpose, not their stings, but their jaws. The young are fed by the females. In the pupa state each is protected by a cocoon.

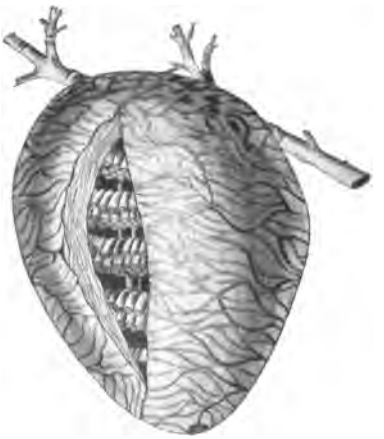

FIG. 110. — HORNET'S NEST.

2. **The Gallfly** punctures the stem or the leaf of a plant, and by means of its ovipositor places its egg within the plant. The larva resides in the wound, and, by the irritation it produces, causes the plant to swell and form the excrescence known as a "gall." The injury done by this is comparatively small, while, on the other hand, gallnuts are many of them used in coloring or in medicine, or form the chief ingredient of ink.

General Characteristics. — Two pairs of membranous wings having comparatively few veins; the head relatively large, with the mouth parts adapted for biting and lapping; the female possessing a sting, ovipositor, or saw; the metamorphosis complete. Most of this order rank high in the scale for intelligence.

General Characteristics of Hexapoda. — The insects thus far considered resemble each other in having the body seg-

mented; in its division into three general regions, — head, thorax, and abdomen; in the possession of antennæ and of compound eyes; in breathing by means of tracheæ; in the possession of three pairs of legs and generally of two pairs of wings; and in a more or less complete metamorphosis.

MYRIAPODA, OR MANY-LEGGED.

The lowest forms among insects are the *centipeds* and *millepeds*.

The Centiped. — A common *centiped* is an insect having a flat segmented body with a distinct head, the thoracic and abdominal segments being similar and continuous.

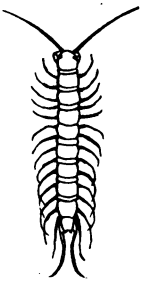

FIG. 111. — COMMON CENTIPED (NATURAL SIZE).

The head bears a pair of long, jointed antennæ. The eyes are simple. Each segment of the body bears a pair of legs. The mouth has labium and labrum, mandibles and maxillæ, and the two pairs of palpi. The alimentary canal is tubular, and so also is the heart, which lies above it, as in other insects, and which forces the blood towards the head. The breathing is by means of tracheæ. The young show their relationship to the larvæ of other insects in having

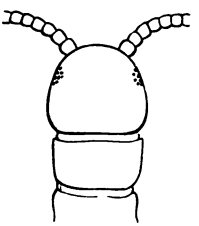

FIG. 112. — MAGNIFIED VIEW OF HEAD OF CENTIPED, SHOWING GROUP OF EYES AT THE BASE OF ANTENNÆ. A few joints only of the antennæ are shown.

but three pairs of legs, and those on the segments just behind the head. The centipeds are usually poisonous,

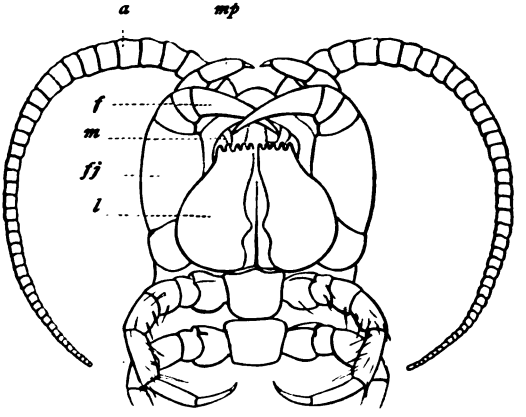

FIG. 113. — MAGNIFIED VIEW OF UNDER SURFACE OF HEAD OF A CENTIPED: *a*, antenna; *mp*, maxillary palpus; *fj*, foot jaw; *f*, poison fang of foot jaw; *l*, labium; *m*, maxilla. The mandibles are hidden behind the other parts, and do not show.

their poison glands emptying through large teeth on the mandibles. The centiped uses this poison to paralyze its victim, being carnivorous.

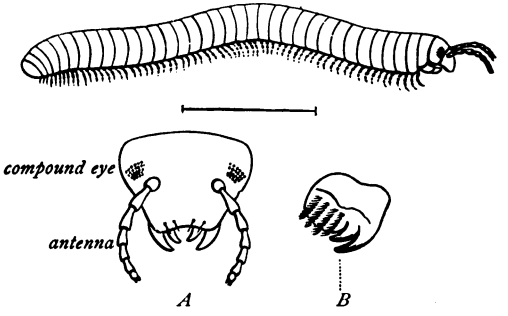

FIG. 114. — A COMMON MILLEPED. The line underneath the figure represents the length of the specimen from which the drawing was made: *A*, magnified view of the head of the milleped represented above; *B*, magnified view of the left jaw.

The Milleped. — This differs from the centiped in having a cylindrical instead of a flat body; in having two pairs of feet to every segment; in having no poison glands; and in having much shorter antennæ. The milleped is herbivorous, though it will eat dead snails or worms.

General Characteristics. — Head distinct; thorax and abdomen plainly segmented and continuous, with numerous segments; and one or two pairs of feet for every segment.

ARACHNIDA, OR SPIDERS, ETC.

Higher than the *Myriapoda*, but lower than the *Hexapoda*, is the subclass *Arachnida*, which includes *spiders*, *scorpions*, and *mites*.

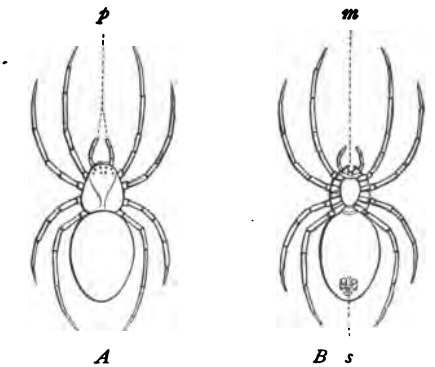

FIG. 115. — COMMON GARDEN SPIDER (EPEIRA): *A*, as seen from above; *B*, as seen from below; *p*, palpi; *m*, mandibles; *s*, spinnerets from which the spider's thread issues.

The Garden Spider. — This is an insect well known to every one, and will serve to illustrate the order. Its body is divided into two general regions, — cephalothorax and abdomen, — united by a slender pedicel. Upon the head

are no antennæ, the first pair of legs being often used as feelers. There are eight simple eyes.

The mouth parts consist of labrum, labium, mandibles, and maxillæ and maxillary palpi. The labrum and labium are grooved on their opposed sides, forming a tube through which liquids may be sucked. The mandibles are toothed, as are also the maxillæ; and the palpi act as feelers, and also for grasping food.

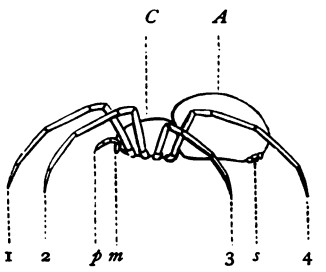

FIG. 116.—SIDE VIEW OF COMMON GARDEN SPIDER: *C*, cephalothorax; *A*, abdomen; 1, 2, 3, 4, first, second, third, and fourth pairs of legs; *s*, spinnerets; *m*, mandibles; *p*, palpi.

There are four pairs of legs, situated upon the thorax. The tarsi are terminated with both hairs and claws.

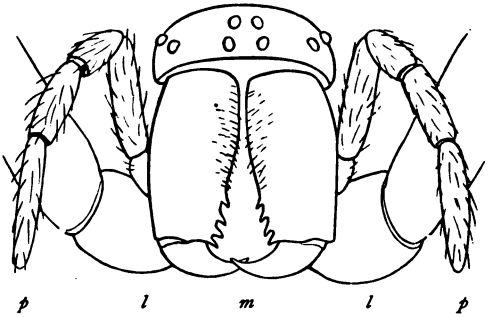

FIG. 117.—FRONT PORTION OF GARDEN SPIDER (GREATLY ENLARGED): *p*, palpi; *m*, mandibles; *l*, portion of first pair of legs; above, front of the cephalothorax, with eight eyes upon it.

Food drawn into the esophagus is passed on through a sucking stomach (similar to that of the butterfly) into a

tubular but rather complex intestine. The spider has, besides salivary glands, another accessory digestive organ, the liver, whose secretion is discharged into the intestine.

The heart of the spider is tubular and dorsal. Spiders have a pair of lungs in the front part of the abdomen. These open by a pair of spiracles on the under side of the body. The blood flows in vessels in the membranous leaves of the lungs, and, becoming purified, passes on into the heart, to be sent into the general circulation. Besides this, the spider's blood is further aërated by a pair of tracheæ whose openings are near the spinnerets.

FIG. 118. — INNER JAWS, OR MAXILLÆ, OF A COMMON GARDEN SPIDER. The first joints of the palpi are seen also.

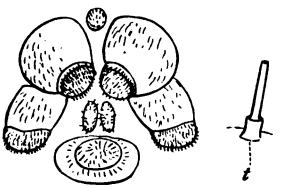

FIG. 119. — SPINNERETS OF A SPIDER: *t*, one of the tubular hairs from the spinnerets (highly magnified).

The spinnerets are located at the end of the abdomen. These consist of three pairs of little prominences covered with tubular hairs, each tube being the outlet for a sepa-

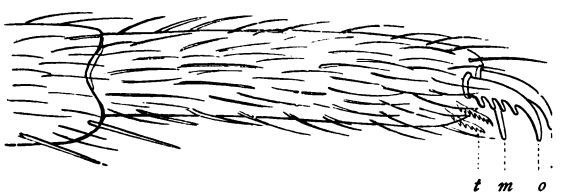

FIG. 120. — END OF A COMMON GARDEN SPIDER'S LEG (MAGNIFIED): *o*, outer claws; *m*, middle claws; *t*, toothed hairs.

rate gland. The glands lie just above the spinnerets. When the spider begins to spin its web, it presses the spinnerets against some object, forcing out from each tube a little fluid, which, upon exposure to the air, hardens into a tiny thread. These threads are usually united to form one stronger and firmer, whose end is securely attached to the object against which the spinnerets were pressed. The spinning is assisted by the hind feet, which guide the thread, and even seem to draw it out.

The web of the garden spider is built in some fence corner or near some crevice where it can hide. Having found suitable upright supports, the spider spins a line across. To do this, it fastens a thread at a proper height. Then it descends the first support and ascends the second, spinning its thread as it goes. Finally it draws this tight, and fastens it securely. From the center of this line it spins threads radiating in every direction, like the spokes of a wheel. This forms a sort of frame-work for its web. After this is complete, the spider begins at the center a spiral thread, which it fastens to each radiating thread as it crosses it. These threads are put rather far apart. After this is finished, another and closer spiral is made, which is begun at the outer edge of the web, and the thread of which is covered with a sticky secretion which adheres to anything with which it comes in contact. As this spiral progresses, the first is bitten away and destroyed. From the center of the web, when it is completed, the spider spins a single thread, whose other end it carries to its retreat, so that, by holding it, it can feel any motion of the web. When an insect becomes entangled, the spider steps cautiously

towards it. Spinning a thread, it holds it with the hind foot so that the victim, in its struggles, will touch and stick to it. This done, it proceeds to spin a thread about the poor unfortunate until it is completely enveloped. It

FIG. 121.— WEB OF GARDEN SPIDER.

was supposed that spiders ate the thread of the web which they bit away; but it is now known that they merely roll it in a ball in the mouth, and then drop it.

The poison glands are at the base of the mandibles, and the poison is discharged through their large fangs. The spider rarely uses these fangs except upon insects suitable for food, and the cases where human beings have suffered seriously from them are rare. Only the soft parts of insects are used as food, the rest being thrown away.

The eggs of the garden spider are laid in a little mass of silk, which is then closely enveloped by more silk to form a cocoon. The eggs are mere drops of jelly. The young are much like the parent except in size, and at first live together. At this time they will eat each other when other food fails. After several molts the spider has attained its full size.

Other Arachnida. — Closely related to the spider are *mites* and *scorpions*.

Notes. 1. **The Trapdoor Spider.** — Some spiders make no webs. Among these are many which capture their prey by leaping upon it. They usually hide under stones, but some make an underground nest. The so-called *Tarantula* (more properly called trapdoor spider), whose bite is incorrectly supposed to be fatal, is a large, hairy spider with very long hind legs. Its nest is often a tubular hole in the ground, which measures about three fourths of an inch in diameter, and several inches in depth. This nest is closely lined with silk, and is covered with a trapdoor, which has a lining and hinge of silk. The eggs are placed in a cocoon, which is either left in the nest or carried about by the mother. The name *Tarantula* is properly applied only to a European species, but we have forms in several parts of our country very similar in both appearance and habit.

2. **The Scorpions** are distinguished by large, forceps-like maxillæ, and by having the body divided into a cephalothorax and a long, segmented abdomen, which is terminated in a powerful sting connected with a poison gland. These insects are most numerous

in the warmer parts of the world; but species of them are found in the Gulf States, in Kansas, and in California.

3. **The Daddy Longlegs.** — Related to the scorpions and spiders is the insect known as the *harvestman* or *daddy longlegs*. In this, the abdomen, though segmented, is short, and the four pairs of legs are long. It is carnivorous, but not poisonous.

4. **Mites.** — Among the mites are some very troublesome insects. One of the large forms is the *tick*, which attaches itself to the skin of an animal or a human being, and gorges itself with blood. Sometimes the insect is completely buried beneath the skin of its victim.

Another mite (much smaller) is the *itch* mite, which buries itself under the skin of its victim, burrowing about, and causing intense irritation.

General Characteristics of Arachnida. — Bodies generally divided into two regions, cephalothorax and abdomen; usually four pairs of legs; simple eyes or none, and no antennæ; only a partial metamorphosis, or none at all.

General Characteristics of Class Insecta. — Body segmented; external skeleton consisting of a horny substance called *chitin;* paired, jointed appendages; nervous system ventral; heart tubular and dorsal; breathing by means of tracheæ.

General Characteristics of Branch Arthropoda. — Both crustaceans and insects have segmented bodies, with the skeleton external, and paired, jointed appendages. Both have the heart dorsal, and the nervous centers ventral.

Suggestions for Review. — Compare a spider with a beetle in external features; in internal organs. In the same way compare the spider with the centiped. Compare a spider with a crawfish in general plan of structure of each. Compare a centiped with an earthworm.

Classification of Arthropoda.

Arthropoda (*Branch.*)

(*Class.*)	(*Order.*)	(*Examples.*)
Crustaceans	1. Cirripedia	Barnacles.
	2. Entomostraca	Cyclops.
	3. Tetradecapoda	Pill bugs, beach fleas.
	4. Decapoda	Lobsters, shrimps, crawfishes, crabs.

(*Class.*)	(*Subclass.*)	(*Order.*)	(*Examples.*)
Insects.	I. Myriapoda	Centipeds.	
		Millepeds.	
	II. Arachnida	Spiders.	
		Scorpions	Daddy longlegs.
		Mites	Ticks.
	III. Hexapoda	1. Thysanura	Bristletails, Springtails, etc.
		2. Neuroptera	Dragon flies, May flies, Case flies, Ant-lions, White ants, Aphis lions.
		3. Orthoptera	Grasshoppers, Locusts, Mantis, Crickets, Roaches, Walking sticks, Walking leaves.
		4. Hemiptera (Bugs)	Cicadas, Aphidæ or plant lice, Bark lice, Bedbugs, Squash bugs.
		5. Coleoptera (Beetles)	Diving beetles, Ground beetles, Tiger beetles, Burying beetles, Spring beetles, Weevils, Ladybirds, Leaf eaters, Longicorns, Blister beetles, Fireflies.
		6. Diptera	Flies, fleas, Mosquitoes.
		7. Lepidoptera	Butterflies, Hawk moths, Moths.
		8. Hymenoptera	Ants, bees, Wasps, Gallflies, Ichneumon flies, Horntails.

Books for Reference.

Packard's Guide to the Study of Insects.
Harris's Insects Injurious to Vegetation.
Kingsley's Standard Natural History.
Lubbock's Ants, Wasps, and Bees.
Emerton's Spiders, their Structure and Habits.
French's Butterflies of the Eastern United States.
Huxley's The Crayfish.
Needham's Lessons in Zoölogy.
Guides for Science Teaching, Nos. 7 and 8.
Insect Life (Government Publication).

Instructions to Collectors.

If one is collecting insects, there is no season of the year when he needs to rest from his labors. In the winter, many insects may be found under the bark of trees or in moss; and pupæ may be found hanging upon trees and fences, or buried a few inches in the ground. In the summer, insects may be captured in all stages and conditions; and night, as well as day, may be well employed in making such collections. The best places for search are gardens and farms, the banks of streams and ponds, and the edges of woods.

Cocoons should be kept in a cool place while the pupa is developing. Galls may be collected in the spring and fall, and kept till the flies appear.

Nets are necessary if one intends to collect to any extent. The *butterfly net* is made as follows: A wire ring, one foot in diameter, is attached to a light wooden handle about four feet long. The net, which is fastened upon the ring, should be of gauze or mosquito netting, the finer and stronger the better. When this net is thrown over the insect, it should be given a twist to close the opening.

A *beating net*, made of a stout, shallow cloth bag, with a stronger rim and shorter handle than the butterfly net, is used to beat bushes and herbs to capture beetles, bugs, and larvæ.

A third net of coarse material may be used for collecting aquatic insects.

A *jar* for killing insects may be made in the following manner: Get a small, wide-mouthed jar with a tight-fitting lid: if a large one is desired, a spring-top fruit jar is a good one. Get a druggist to put four or five pieces of cyanide of potassium, the size of walnuts, into the jar, and cover them with a layer of liquid plaster of Paris. When the plaster of Paris hardens and dries, the jar is ready for use. Cyanide of potassium is deadly poison, and should not be handled carelessly. The fumes are sufficient to cause severe headache if breathed any length of time. They quickly kill most insects. The jar should be kept closed.

Butterflies may be quickly killed by pinching the thorax, if no cyanide bottle is at hand. Other large insects, whose wings would be injured in such a jar, should be killed with chloroform, or ether, or the fumes of sulphur. Beetles and larvæ may be killed in alcohol.

One good way to collect butterflies and moths is to get the caterpillar, feed it upon the leaves of the plant on which it was found, and watch it through all the changes of its metamorphosis. Besides the perfect insect, you will have acquired some interesting and valuable information.

Many insects are attracted by light; and a lamp set at night in an open window forms a successful lure for moths, beetles, and other night flyers. Some collectors paint trees with a mixture of rum, beer, and sugar; and late in the evening they go out to collect, by the aid of a lantern, the insects attracted and stupefied by the fatal sirup.

Collecting boxes should be lined with cork, to which the insects may be pinned. Butterflies and moths may be laid between the leaves of a square of paper which has been folded diagonally into a triangle. Then the edges should be folded over. In this way many insects may be packed together in a tin box, and shipped any distance. Dried specimens to be spread for mounting may be softened by laying them for a day or two in a box containing wet sand covered with a layer of paper.

To spread the wings of butterflies, moths, dragon flies, etc., a *mounting board* is needed. Two boards should be so placed upon a third that their approximate edges are half an inch apart, or less for the smaller species; and the two should slope slightly downwards towards this space between, which should be an inch in depth with a strip of cork lining the bottom. Into this groove the body of the insect is pinned. The wings are spread upon the sloping boards, and held in place by strips of paper laid across them, and pinned down.

Most insects should be pinned through the thorax, but beetles through the right elytron, close to the scutellum. Very small insects may be gummed across an acute corner of a small triangular card, and that pinned instead.

Insect pins can be obtained from any optician. They are longer, more slender, and have smaller heads, than common pins.

Insect boxes or drawers should have cork bottoms.

When it is possible to get both male and female of any insect, they should be pinned side by side. All insects should, as far as possible, be classified. A slip of paper, upon which are the common and scientific names and the date and place of capture, may be pinned under the insect.

An ambitious entomologist will keep a record of all the insects he captures, with notes as to time, place, plant upon which each was found, and any other information which may be useful in establishing its identity, or in determining its habits. Such notes are sometimes exceedingly valuable.

BRANCH VIII.—VERTEBRATA.

THE vertebrates are animals that are distinguished from all others by the possession of a *backbone*, dividing the body into two cavities,—one for the vital organs, and one for the nervous system. This backbone is in most of the forms composed of a series of irregular bones called *vertebræ*, which have pads of cartilage between them, the whole chain being more or less movable. A further difference between vertebrates and invertebrates is in the relative positions of nervous and circulatory systems, as will be seen in Fig. 123. Among the vertebrates there are a number of classes distinguished from each other, not only by the character of this backbone, but by other structural differences. The lowest classes contain but one or two forms each, which, being

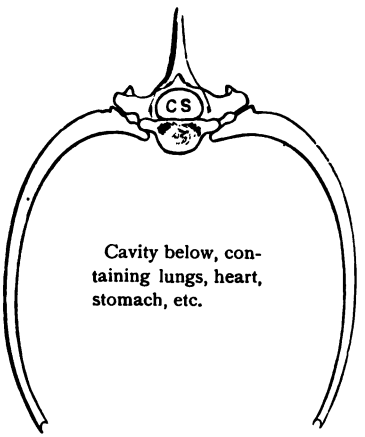

FIG. 122.—A VERTEBRA AND A PAIR OF RIBS FROM A CAT: *CS*, cavity for cerebro-spinal cord.

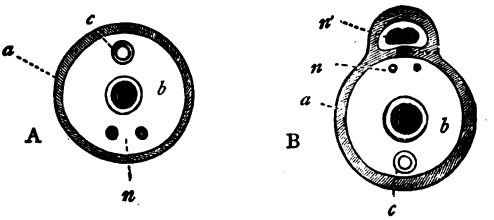

FIG. 123. — DIAGRAMS SHOWING TRANSVERSE SECTIONS OF ONE OF THE HIGHER INVERTEBRATA (*A*), AND ONE OF THE VERTEBRATA (*B*): *a*, wall of the body; *b*, alimentary canal; *c*, blood-vascular system; *n*, nervous system; *n'*, cerebro-spinal axis or brain and spinal cord, inclosed in a separate tube.

marine and confined to special localities, are not familiar to the general student. The lowest class generally known is that of the *Fishes*.

PISCES.

The Fresh-water Perch. — The form selected to illustrate this class is the *fresh-water perch*, as it is widely distributed, and as there is a very similar salt-water form. There are other fresh-water forms closely related which may be used instead, if necessary.

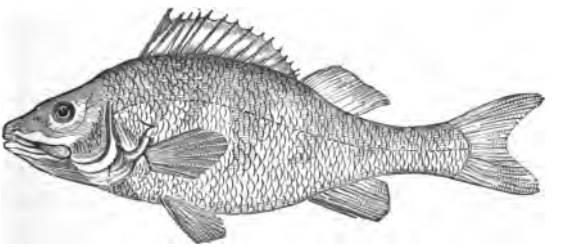

FIG. 124. — THE COMMON PERCH (PERCA FLUVIATILIS).

The body of the perch tapers at each end, and is flattened (or *compressed*, as it is called) from side to side. It

is covered with overlapping scales. These are rounded on their free edges. They are ossifications of parts of the true skin, or cutis, and covered by the cuticle.

Unlike most of the animals of preceding branches, the fish possesses an internal skeleton, which, in the perch, is fairly well ossified. The backbone of the perch consists of forty vertebræ, which are concave on both surfaces of the body, or solid portion. The skull consists of a number of pieces joined by sutures. To this is attached a mov-

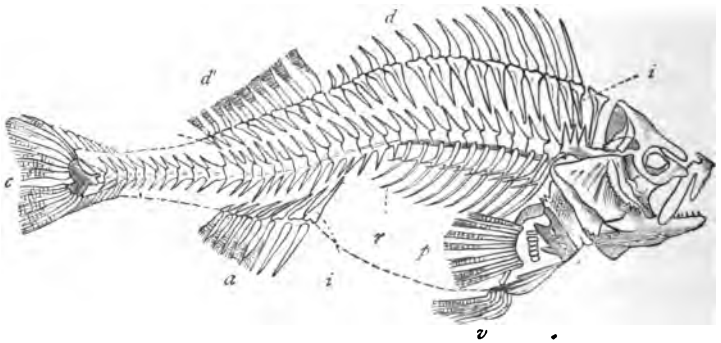

FIG. 125.—SKELETON OF THE COMMON PERCH: *p*, pectoral fin; *v*, one of the ventral fins; *a*, anal fin, supported upon interspinous bones; *c*, caudal fin; *d*, first dorsal fin; *d'*, second dorsal fin, both supported upon interspinous bones; *i*, interspinous bones; *r*, ribs.

able lower jaw, the opening of the mouth being transverse, and not, as in the *Arthropoda*, in the line of the length of the body. The upper jaw of the perch is movable also. The head is joined closely to the trunk, there being no neck present.

There are two pairs of fins, *pectoral* and *ventral*, which correspond to the paired limbs of other vertebrates. These limbs are attached to the backbone by means of

the shoulder and pelvic girdles respectively. The ribs are small and numerous, and hang free in the flesh, there being no sternum developed.

There are other fins on the perch which are unpaired, being on the median lines of the body, and consisting of a

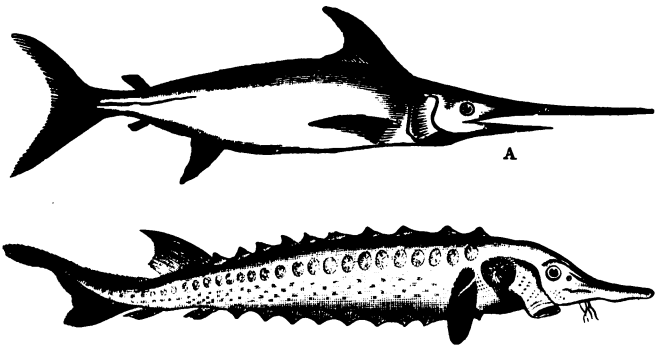

FIG. 126.—*A*, SWORDFISH, SHOWING HOMOCERCAL TAIL; *B*, STURGEON, SHOWING HETEROCERCAL TAIL.

fold of the skin supported by cartilaginous rays or spines. The fold upon the back is divided, making two *dorsal* fins. The fin forming the tail is the *caudal* fin; the one on the under side, the *anal* fin. The caudal fin has two lobes. These being equal in the perch, the tail is said to be *homocercal.* In some fishes they are unequal, when the tail is said to be *heterocercal.*

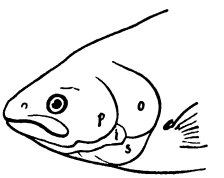

FIG. 127.—HEAD OF FISH: *p*, preoperculum; *o*, operculum; *s*, suboperculum; *i*, interoperculum.

Just back of the head on each side of the fish is a slit-like opening. This is the outlet from the gills. This out-

let is protected by an *operculum*, or gill cover, whose free edge is turned backward.

The mouth of the fish widens into a pharynx, or *branchial chamber*. On each side of this are the breathing organs, or *gills*. Each set is supported by four arches, between which are the gill slits. The gills themselves are membranes which contain numerous capillaries. Water containing air particles enters the mouth, passes into the pharynx and out through the gill slits, escaping from under the operculum, in its passage having bathed the gills. The blood in the gill capillaries takes oxygen from the air contained in the water, and gives off waste material.

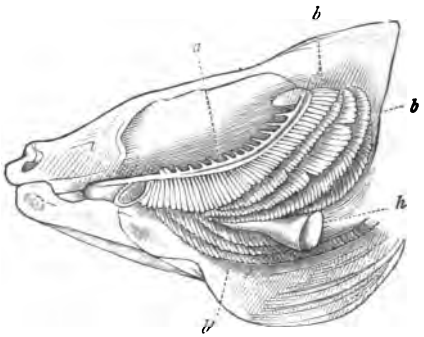

FIG. 128. — GILLS AND HEART OF THE PERCH, EXPOSED BY REMOVAL OF GILL COVER ON LEFT SIDE: *a*, first of the four bony arches which carry the gills; *b*, gills; *b'*, lower edges of gills on the right side; *h*, heart.

The fish has cold but red blood. It is cold because of the sluggish circulation, the chemical changes being slow in consequence. The heart, which is ventral, is two-chambered, possessing one auricle and one ventricle, which correspond to the right auricle and right ventricle of a four-chambered heart. Venous blood enters the heart. It is pumped from auricle to ventricle, and thence to the *arterial bulb*, its back flow being prevented by a valve. The arterial bulb, a short muscular cylinder, runs forward, and is continued by the aorta. This latter

divides into branches to the gills, where the blood is distributed in capillaries for its purification. It is again collected into a single artery, through whose branches it is sent into all parts of the body to supply food and oxygen to the cells; and having been deprived of these, and having received in exchange waste products, it returns by veins to the heart.

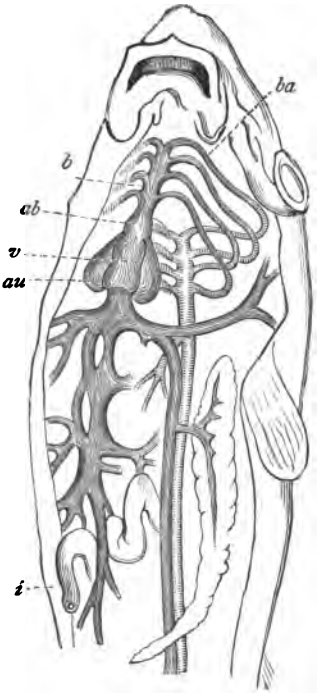

FIG. 129. — DIAGRAM OF CIRCULATORY SYSTEM IN A FISH. The vessels containing venous blood are longitudinally shaded; those containing arterial blood, cross-shaded: *au*, auricle; *v*, ventricle; *ab*, arterial bulb; *b*, branchial artery; *ba*, one of the divisions of the branchial artery going to the gills; *i*, intestine.

The digestive apparatus of the perch is rather simple. There are closely crowded rows of teeth on the jaws, and a group of them on the vomer in the roof of the mouth. There are no salivary glands. The esophagus is short, and ends in a stomach, which is scarcely more than a dilated portion of the tubular intestine. The latter is short, and not nearly so winding as in man. The light-brown liver lies above the stomach. This is the only

accessory digestive organ. As in man, its secretion is stored in a gall bladder. The fish has the mucous lining of its intestine increased by folds; and in this lining are absorbing vessels, the lacteals, through which much of the digested food is first taken up. The fish has a spleen close to the stomach.

The fish has in the thorax an air bag which is homologous to the lungs of other vertebrates; that is, it is similar

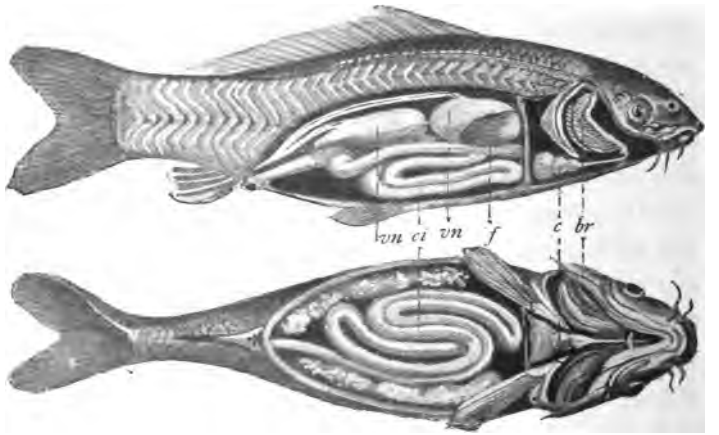

FIG. 130.—ANATOMY OF THE CARP: *br*, branchiæ, or gill openings; *c*, heart; *f*, liver; *vn*, swimming bladder; *ci*, intestinal canal.

in position, and somewhat in structure. It is not, however, used as a lung, being a simple sac filled with a gas. Its purpose is to enlarge the body, and diminish the specific gravity.

The nervous system of the fish, as of all vertebrates, is most easily described by comparing it with that of man. It has a brain which lies in the skull cavity, a spinal cord protected by the spinal canal, and nerves connecting these

centers with the rest of the body. The brain contains the same divisions as that of man, but differs greatly from his in size and development. The *cerebrum*, or organ of thought, is relatively small, and correspondingly the fish has little intelligence. The arrangement and distribution of the nerves in the fish and other vertebrates is somewhat similar to that of man.

The eyes of the fish are set in sockets: they are unprotected by eyelids. The nasal passages are blind sacs; that is, they have no connection with mouth or throat. Odors are perceived in the water, which must enter and pass out through the same opening. The ear has no external opening.

The fish is propelled through the water principally by the movement of the tail. The median fins assist in preserving its balance; and the paired fins, in its rising and falling in the water.

The reproduction of the perch is by eggs, of which a great number are produced at a time by the parent fish, and are placed in slight hollows in shoal places in ponds. They hatch in twelve days. The young fish at first differs in form somewhat from the parent, especially in the shape of the tail. It cannot, however, be said to undergo a metamorphosis.

Other Fishes. — Related to the perch are many bony fishes, some of which are valuable for food; others are remarkable for their curious or beautiful forms.

Notes. 1. **Food Fishes.** — In one family are included many valuable food fishes, — the *salmon*, *trout*, *grayling*, and *whitefish*. The salt-water salmon of the Pacific ascends rivers in the autumn to spawn, going as high as possible upstream. It

lives in the north temperate and arctic seas. The eggs are placed in a broad, shallow nest excavated by the male, and are covered with stones and gravel. The parent fishes probably die of exhaustion, or of the injuries received in their long journey inland, especially in ascending rapids and falls. The young are hatched in two months, and, with the spring floods, seek the ocean. The Atlantic salmon does not ascend rivers to such a distance. Its young, called the *parr*, remains about two years in the river, descending at the end of that time to the sea, when it is called *smolt*. In the sea it continues its growth, and becomes more silvery in color, being then called the *grilse*. It then develops rapidly into the full-grown salmon. One of the most beautiful of this family in its coloring is the Eastern *brook trout*. It is speckled with red, and the back mottled and barred with olive.

2. **The Minnow** belongs to the same family with the *shiners* (gold and silver fish), the *stone rollers*, the *chub*, the *dace*, and other *carp*. They are numerous in the fresh water of the Old World and of North America. They are weak and small, and their mouths toothless.

3. **The Shark.** — Among fishes whose skeletons are never ossified are the *sharks*. They are all large fishes, with unprotected gills, with the mouth on the under side of the snout, with naked skin, and with the tail heterocercal. The mouth is armed with numerous rows of sharp, conical, but flattened teeth, not set into sockets, but in the membrane of the mouth. They point backward. The shark is an enemy dreaded by almost all other marine animals.

FIG. 131. — SHARK.

General Characteristics. — Internal skeleton consisting of a jointed backbone, a skull, and two pairs of limbs (called fins), attached to the backbone by shoulder and pelvic girdles; the body divided by the backbone into two cavities, — a dorsal for the nervous system, and a ventral for the vital organs; body covering usually scales; breathing by gills; heart with two chambers; blood red but cold; nervous system with brain, spinal cord, and nerves; cerebrum not well developed; reproduction by eggs.

CLASSIFICATION.

(*Class.*)	(*Subclass.*)	(*Examples.*)
Pisces	Teleostei	Perch, salmon, minnow.

BATRACHIA.

The Frog. — The typical form in this class is the *frog*. Like the fish, it possesses an internal skeleton more or

FIG. 132. — THE COMMON FROG (RANA TEMPORARIA).

less ossified. The body covering is a smooth, moist skin, yellowish brown, mottled with green or with darker brown

markings and spots. The ventral surface is lighter, usually buff, without markings. There being neither neck nor tail, the body is short and thick. The head is triangular, with a wide mouth, and large, staring eyes. Back of each eye is a circular membranous disk, differing in color from the surrounding skin. This is the membrane of the tympanum or ear drum.

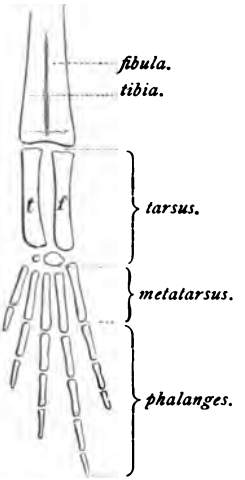

FIG. 133. — BONES OF THE RIGHT LEG OF A YOUNG TOAD (GREATLY ENLARGED): the femur not shown; the tibia and fibula combined.

The frog has two pairs of limbs. The fore pair are short, with four toes, which are neither webbed nor clawed. These four toes correspond to the four fingers of man's hand, the thumb being rudimentary. Upper- and fore-arm bones are present, and so also are hand bones. The hind leg is long, and adapted for leaping. Thigh, leg, and foot bones are developed, and all five toes, which are united by webbing, to adapt the frog for swimming.

FIG. 134. — SKELETON OF FROG.

The skull bones are not well ossified, and they do not form an entire case for the brain, as they do in man. There are but nine true vertebræ in the backbone, the last being the sacrum. But following the

sacrum is a long, solid piece, which tapers to a point at its hinder end. This is regarded as representing a number of vertebræ fused together. The body of each vertebra (with one exception) is concave in front, and convex behind. The limbs are attached by means of shoulder and pelvic girdles. There are no ribs present, but there is a sternum consisting of several pieces.

The mouth of the frog is peculiar. The fleshy, forked tongue is attached in front to the floor of the mouth, and, when not in use, points backward. It is used in capturing insects, a sticky secretion aiding in so doing. Along the edge of the upper jaw is a row of fine, almost bristle-like teeth, and two groups of similar teeth are close together on the roof of the mouth. There are several openings into the mouth, — two from the nasal passages, whose external openings are just below the eyes; two from the ears; one into the larynx; and one backwards into the esophagus. The remainder of the alimentary canal consists of a stomach and a slender, winding, small intestine, and a broader, but short, large intestine. The accessory organs of digestion, liver and pancreas, are present, and their secretions, as in man, are poured into the duodenum. These organs — in fact, all the organs of the frog — much resemble those of man in shape and position. The spleen is also present. There is a rudimentary diaphragm situated above instead of below the lungs.

The frog breathes by lungs. These lie in the part of the trunk nearest the head. A slit-like opening in the floor of the mouth is the glottis. It communicates with a short chamber which is larynx and trachea united. In the top of this are the vocal chords, by the vibration of

which the croak of the frog is produced. These are better developed in the male than in the female. The trachea opens into two lungs, which are divided into air cells. Upon the membranous walls of these, capillaries are spread for the purification of the blood. Inspiration is peculiarly effected in the frog. The mouth is closed and its floor depressed. Air enters through the nostrils, and, the mouth being filled, the nostrils are closed, as is also the opening into the esophagus. The floor of the mouth being then raised, the air is forced through the glottis into the lungs. The frog cannot inspire with his mouth open.

Besides this purification of the blood in the lungs, a great deal of oxygen is absorbed through the skin, which is abundantly supplied with capillaries, and is kept moist for the purpose.

The heart of the frog lies between the lungs and above the stomach, on the ventral side of the body. It is conical, with the apex downward, and is inclosed in a membranous

FIG. 135. — BLOOD CORPUSCLES (MAGNIFIED): *a*, man; *b*, goose; *c*, crocodile; *d*, frog; *e*, skate.

sac, — the *pericardium*. The cavities of the heart are three, — two auricles and one ventricle. The ventricle receives at the same time both venous and arterial blood, but it is so arranged that they are not much mingled, and, leaving it, are properly distributed. The frog's blood is red. The red corpuscles, unlike those of man, are oval and nucleated. The frog has also a set of vessels for the circulation of

lymph. Besides this, the skin is very loose, and between it and the body, as well as in other spaces in the interior, there is a quantity of lymph. This is kept in circulation, and connected with the red-blood circulation, by means of two pairs of *lymph hearts.* These are sacs whose muscular walls pulsate, and pump lymph from the lymphatics and the spaces of the body into veins. These lymphatics, like those of man, are the drainage system of the body.

The nervous system of the frog is divided into two parts, — the *cerebro-spinal* and the *sympathetic.* The centers for the former are the brain and spinal cord. The nerves of this division supply the special sense organs and the voluntary muscles. The centers for the sympathetic system are a number of ganglia in front of the spine, whose fibers connect not only with the vital organs and other parts whose action is involuntary, but also with the cerebro-spinal system.

The eye is very well organized, having the same coats, humors, lens, and distribution of optic nerve as the human eye. It is also lodged in an orbit, and moved by several muscles. Its protection consists of two eyelids. The upper is large, opaque, and not very movable; the lower is semitransparent, and can be drawn up to meet the upper.

The ear corresponds to the middle and internal ear of man. It connects with the mouth by the Eustachian tube.

The tongue is supplied with a nerve of taste, and the nasal passage with an olfactory nerve. Touch is keen in the skin.

The reproduction of the frog is by means of eggs. These are laid in the early spring in the water of ponds

and brooks. They are dark-colored, about as large as good-sized pin heads, and are coated with albumen, which, swelling up in the water, protects them. The development of the egg depends on the temperature. Before the young frog, which is called a *tadpole*, leaves the enveloping albumen, it is fish-like in form, without limbs, and has two adhesive disks on the under side of the head, by means of which, when free, it clings to water

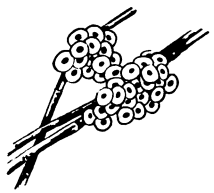

FIG. 136. — EGGS OF FROG.

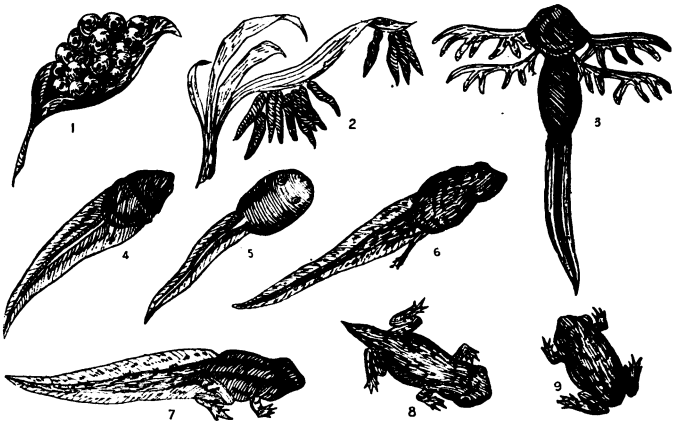

FIG. 137. — EGGS, TADPOLES, AND FROGS: 1, eggs; 2, larvæ; 3, tadpole with branching gills: 4, gills absorbed; 5, back view of 4; 6, with hind legs; 7, with hind and fore legs: 8, with legs elongated and tail shrunk; 9, perfect frog.

plants. As time progresses, the tadpole goes through many changes in both external and internal structure, so that it is said to pass through a complete metamorphosis. Immediately after its escape from the albumen,

branching gills appear. The water enters the mouth and passes out through these. A few days later these external gills are absorbed, and internal ones are developed. Then the limbs begin to grow, the hind pair becoming visible first. At the same time lungs are developed, though the internal gills are retained till the animal is about mature, when these gills also disappear. As the legs elongate, the tail shortens, and finally is absorbed. In the mouth, during this time, the teeth have developed, and the frog becomes insectivorous, whereas the tadpole lives on vegetable diet.

There are several species of frogs in the United States, all much alike in appearance and habits. The largest is the bullfrog.

Other Batrachia. — Related to the frog are *toads*, *tree toads*, and *salamanders*.

The eggs of the toad, like those of the frog, are laid in the water. They may be distinguished by the fact, that, instead of being massed together irregularly, they are arranged in strings which coil spirally. The tadpole of the toad undergoes the same metamorphosis as that of the frog. The toad differs from the frog in having a dry, warty skin, in having no teeth, and in leaving the water and living in dry holes. It destroys many insects injurious to vegetation. It is perfectly harmless.

FIG. 138. — THE COMMON TOAD.

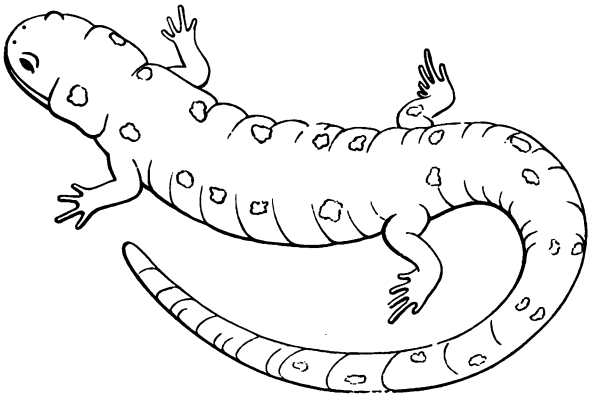

FIG. 139. — COMMON YELLOW SPOTTED SALAMANDER.

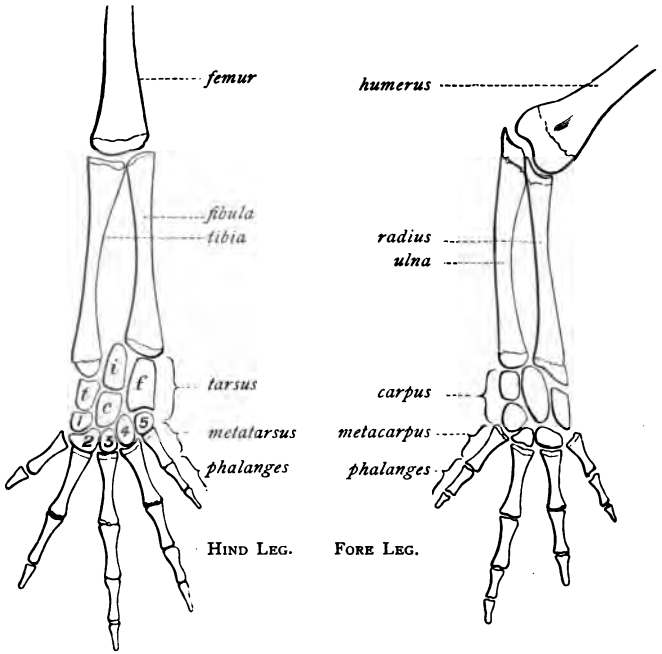

FIG. 140. — HIND AND FORE LEG OF SALAMANDER (ENLARGED).

The salamander, like frog and toad, develops in the water, undergoing a metamorphosis which is not, however, complete, the animal retaining its tail through life. Some forms, like the *mud puppy*, remaining about the water, retain the external gills, though the internal are not present, and true lungs are developed. The limbs in these are not so well developed as in frogs and toads.

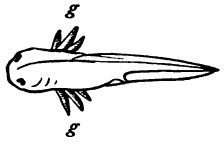

FIG. 141. — YOUNG SALAMANDER: *g*, gills.

General Characteristics. — Development in the water, with more or less complete metamorphosis; breathing by gills, and afterwards by lungs; limbs developed in later stages; heart with three cavities; red, cold blood; skin naked; reproduction by eggs.

CLASSIFICATION.

(*Class.*)	(*Order.*)	(*Examples.*)
Batrachia	Urodela	Salamanders.
	Anura	Frogs, toads, tree toads.

Books for Reference on Fishes and Batrachians.

Kingsley's Standard Natural History, vol. iii.
Jordan and Gilbert's Synopsis of Fishes of Eastern United States.
Davis's Text-Book of Biology.
Martin and Huxley's Practical Biology.
Needham's Lessons in Zoölogy.
Jordan's Manual of Vertebrates of Eastern United States.

REPTILIA.

This class contains the orders to which belong the snakes, lizards, turtles, crocodiles, and alligators, as well

as many extinct animals whose fossil forms are preserved for us in the rocks. The four orders of living forms will be treated separately.

OPHIDIA.

The Garter Snake. — The *snake* will be well illustrated by one of our harmless serpents, the common *garter snake.* This has a long, cylindrical body with a pointed tail. The body covering consists of scales, which are a development of the epidermis. They are small and numerous above,

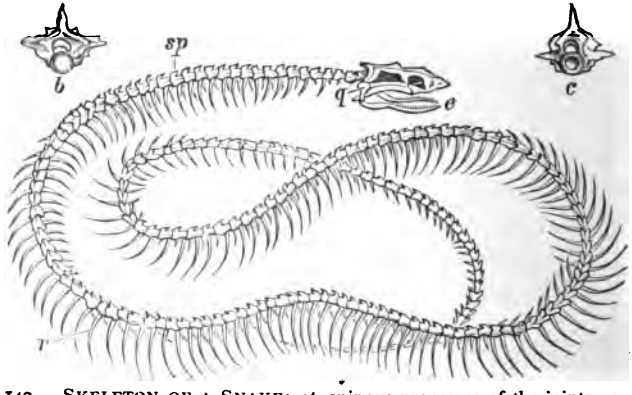

FIG. 142. — SKELETON OF A SNAKE: *sp*, spinous processes of the joints; *r*, ribs; *q*, quadrate bones, joining upper and lower jaws; *e*, front of lower jaw, where there is an elastic band in the place of bone; *b*, ball end of joint, facing the tail; *c*, cup end of joint, facing the head.

but on the ventral side each scale extends across the body. The ventral scales overlap backwards, and, being moved by muscles and attached to the ribs, they serve as organs of locomotion. The general coloring of a garter snake is brownish or blackish, but there are three longitudinal yellowish dorsal bands, which in some species are very distinct.

The eyes of the snake have no movable lids; but they have a permanent extra membranous or horny covering, between which and the cornea is a little lachrymal fluid.

The internal skeleton is peculiar. The backbone consists of many vertebræ, whose bodies or *centra* are concave in front, and convex behind, so as to move as by ball-and-socket joints. They are so arranged as to give strength, combined with very free movement. Attached to each vertebra except the first (or *atlas*) is a pair of ribs, the lower ends of which are attached to the ventral scales. There are no limbs developed.

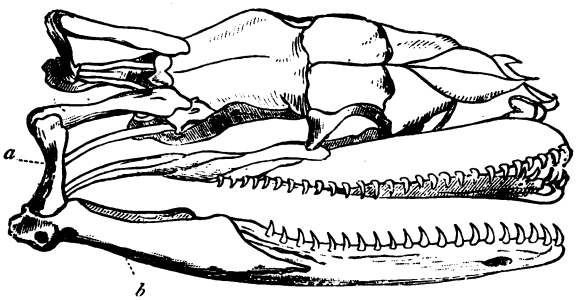

FIG. 143. — SKULL OF A SERPENT (PYTHON): *a*, quadrate bone; *b*, lower jaw, articulating with the movable quadrate bone (*a*).

The mouth is peculiar also. The lower jaw is not directly attached to the upper, but there is on each side a bone, called the *quadrate bone*, which intervenes. In the snake, this bone is movable; the bones of the lower jaw are only united by ligaments; and so much can the mouth of the snake be dilated, that it swallows its prey (which often consists of frogs, toads, etc.) whole. In the mouth are sharp, conical teeth, which point backwards. These are not set in sockets, and are only used for grasping, and never for masticating food. The tongue is long,

slender, and forked, and can be darted out with great rapidity. It is withdrawn into a sheath.

The digestive apparatus is much like that of the frog. The intestine is not so winding, and the organs are arranged so as best to be accommodated in the slender body.

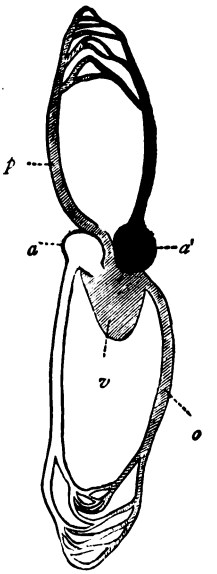

FIG. 144. — SKETCH DIAGRAM OF THE CIRCULATION OF A REPTILE: *a*, right auricle, receiving venous blood from the body; *a'*, left auricle, receiving arterial blood from the lungs; *v*, arterio-venous ventricle, containing mixed blood, which is driven by *p* (the pulmonary artery) to the lungs, and by *o* (the aorta) to the body. The venous system is left light, the arterial system is black, and the vessels containing mixed blood are cross-shaded.

The larynx is better developed than in the frog, and the trachea is longer. Owing to the slender body of the snake, only one lung is developed, and this is elongated. The other lung is minute and rudimentary.

The heart has two auricles and one ventricle. This latter has a membranous partition, which hangs so as partly to separate venous from arterial blood. The blood is cold.

The nervous system consists of the same divisions as that of other vertebrates. The brain is relatively small. Neither sight nor hearing is acute in the snake; the animal depending, both in its search for food and in its escape from its enemies, on touch and smell,

which are keen. The ear is only an internal organ. The nostrils are close to the end of the snout. The sense of taste is probably entirely lacking, the snake usually swallowing its prey alive and whole.

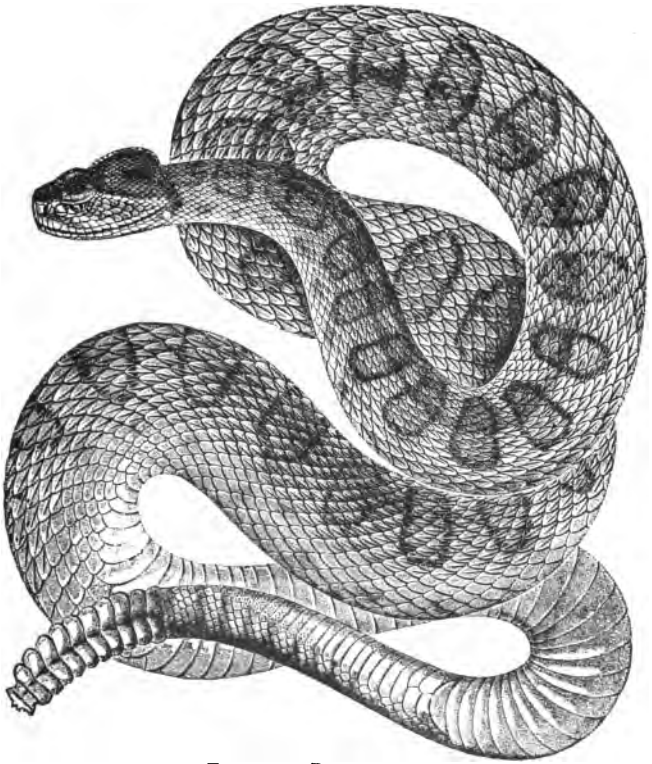

FIG. 145. — RATTLESNAKE.

The outer covering of scales is shed, as a whole, at regular intervals.

The garter snake hibernates in the winter.

Reproduction is by means of eggs.

Other Snakes. — Closely related, harmless snakes are the *spreading adders, black snakes* and *racers, green snakes, king snakes, house adder* or *milk snake, ring-necked snakes,* etc.

Among the venomous snakes of North America are the *rattlesnakes, copperhead,* and *moccasins.* They are most common in the South and West, where the country is thinly settled, these snakes having been nearly or quite exterminated in the densely populated districts. They are characterized by large heads, and *keeled* or *carinated* scales. The upper jaw of each of these snakes is destitute of the ordinary reptilian teeth, but has on each side an erectile poison fang. At the base of this fang is a poison gland, from which the secretion flows down, through a tube in the fang itself, into the wound inflicted. These fangs can be extracted, but they are replaced after a time.

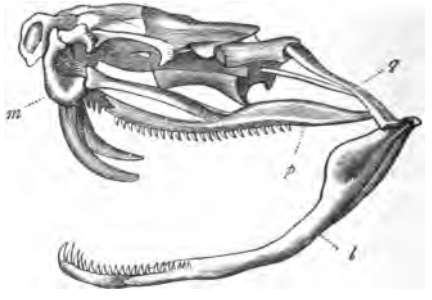

FIG. 146. — SKULL OF RATTLESNAKE: *l*, half of lower jaw united to the skull by quadrate bone; *q*, quadrate bone; *m*, upper jaw, carrying poison fang; *p*, series of teeth upon the palate.

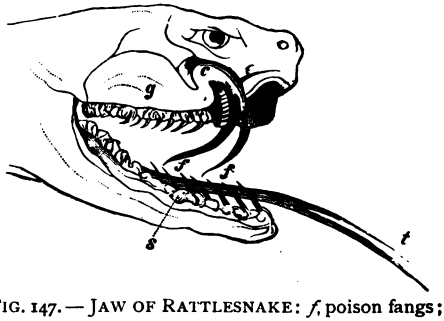

FIG. 147. — JAW OF RATTLESNAKE: *f*, poison fangs; *g*, poison gland; *c*, canal leading from gland to base of fang; *t*, harmless tongue; *s*, saliva glands.

Notes. 1. **The Rattle** of the rattlesnake consists of pieces of horny epidermis which are jointed together, and attached to the end of the tail. The noise made by them resembles that of the cicada, and gives warning of the presence of the snake. The number of rattles does not at all indicate the age of the individual.

2. **The Bead Snake.** — Another venomous snake found in the warm parts of our country is the *bead* or *harlequin* snake. This is jet black, with broad crimson rings about the body, each bordered with yellow, and spotted below with black. This has a mild disposition, and, although it has the poison fangs, is usually harmless.

LACERTIA.

The Lizard. — The *lizard* most common in the United States is the *tree swift* or *pine-tree lizard.* This has a cylindrical body, and long, slender tail. The body covering consists of small, overlapping scales, developed from the epidermis. These are shiny, and are blue, green, or bronze in color, marked with black wavy bands above, bright-colored along the sides.

FIG. 148. — LIZARD.

The lizard has both pairs of limbs developed, with five long, clawed toes on each foot. The vertebræ of the lizard have the centra convex in front, and concave behind. The caudal vertebræ are peculiar in having a cartilaginous

septum through the middle of each; and at this point the vertebra divides readily. Since the tail consists of little but bone and skin, it is very brittle; so that it is a very common occurrence for the lizard to lose its tail. It is renewed in time, but probably never is as long and slender as it was originally. Both pectoral (or shoulder) and pelvic girdles are developed, as is also a sternum. The ribs are upon dorsal and lumbar vertebræ.

The lower jaw bones are firmly united, and the mouth is not dilatable. Both jaws are set with teeth. The

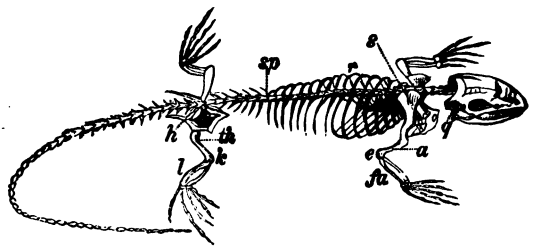

FIG. 149. — SKELETON OF A LIZARD: *sp*, spinous processes, which in the tortoise are flattened into plates; *r*, ribs; *s*, shoulder bone; *a*, upper arm; *e*, elbow; *fa*, forearm; *h*, hip bone; *th*, thigh bone; *k*, knee; *l*, bones of the leg; *q*, quadrate bone between upper and lower jaw.

tongue is not sheathed, but is long and forked, and is used in capturing insects upon which the lizard feeds. The digestive apparatus is well developed.

The heart has three chambers, like that of the snake, and the blood is cold. The lungs are well developed. The nervous system is like that of other reptiles. The brain is relatively small.

The eyes are protected by two eyelids. External ear cavities are present, with membranous tympani.

The lizard is perfectly harmless, and loves to lie basking in the sun; but it is very shy, and, when disturbed, it

disappears with such rapidity as to deserve its name of "*swift.*" The eggs of the lizard are placed in sand or soil to hatch.

The Chameleon. — Related to this lizard is the *Anolis*, or Southern *chameleon*, as it is called, though it is not a true chameleon. It has the power to change its color, so that it varies from almost white, through beautiful shades of green and bronze. This variation in color is supposed to be due to the pigment cells being under nervous control. The chameleon has below, along the throat, a loose fold of skin. The animal is easily tamed, and may be fed upon sirup and insects.

The Horned Toad. — Another American form is the *horned toad* of the South and West. It has been incorrectly called a toad because of a fancied resemblance to that animal. The body is somewhat circular, is depressed, and has a short, conical tail. Its covering consists of spiny scales. The head has a crown of large spines. The eyes are small, and protected by ridges which run backward above them. The general coloring of the animal is brownish, imitating the color of its surroundings. It lives in dry places, especially in desert regions. It is harmless and easily tamed, delighting to be handled if one is not rough with it. It feeds upon insects, but will eat earthworms, and will also take milk.

Notes. 1. **The Gila Monster.** — The one poisonous lizard in existence is found in the southwestern part of our continent, the *Gila monster*, or *heloderma*, which grows to be over three feet long. It has a clumsy body, ornamented with horny scales and tubercles. The general coloring is black and yellow. Its bite is poisonous, but not always fatal. The poison differs from that of

venomous snakes in attacking the heart and spinal cord and producing paralysis.

2. **The Glass Snake** is a footless lizard of the Southeastern States. It is snake-like in appearance; but its tail, like that of other lizards, is very brittle. From these two facts it gets its name. The glass snake burrows in dry soil or hides in the roots of a tree. When disturbed, its movement is extremely rapid; and if one undertakes to capture it, it is impossible to secure a perfect specimen, as the slightest blow fractures it, or the animal itself, in its endeavors to escape, throws off its tail. As with other members of the order, a lost tail will be replaced. The parts of the animal, when once separated, never come together again, as is so often stated.

TESTUDINATA.

The Turtle. — The *turtle* is distinguished from other reptiles by the possession of a shell, the upper piece of which is called the *carapace*, the lower the *plastron*. Within this covering, the turtle can withdraw its head, limbs, and tail. The carapace consists of the dorsal vertebræ and ribs, immovably united, and covered without by horny epidermal plates. The plastron does not correspond to the sternum, which seems to be wanting. It is rather a development from membrane. There are five toes upon each fore foot, four upon each hind foot, and the toes are clawed. The shoulder and pelvic girdles are developed. The tail is short and tapering.

The turtle has a horny beak, like a bird's. The tongue is spoon-shaped and immovable. The digestive apparatus is otherwise much as in other reptiles.

The lungs are well developed; but, as in the frog, the air is taken in by an act like swallowing.

The heart is three-chambered, and the blood is red and cold.

The eye has two eyelids and a *nictitating membrane*, which is semitransparent, and is used to shut out part of

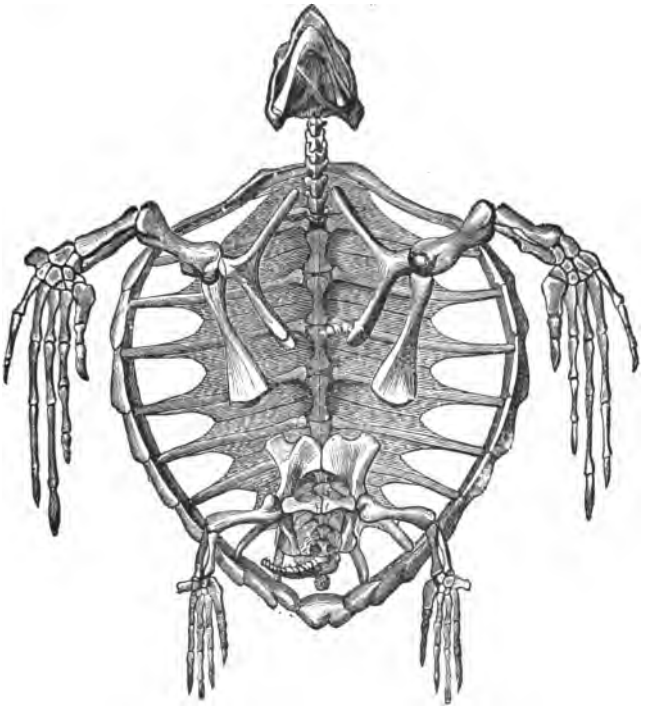

FIG. 150.—SKELETON AND CARAPACE OF THE LOGGERHEADED TURTLE (VIEWED FROM BELOW), THE PLASTRON BEING REMOVED.

the light when the glare is too strong. Hearing is acute, the ear being fairly well developed. The membrane of the tympanum is exposed.

The carapace of the common *box turtle* is high and arched. The plastron is divided transversely, so that the

shell can be completely closed at will. The general coloring is blackish, variegated with yellow. The animal attains great age.

The eggs are laid in the sand, where they are hatched by the heat of the sun.

FIG. 151. — BOX TORTOISE.

Other Testudinata. — Related are the terrapins, snapping turtles, wood turtles, soft-shelled and leather turtles, and marine turtles.

Note. — In the marine turtles the limbs are developed as flippers. The tortoise shell of commerce comes from the epidermal plates of a marine turtle. Another marine form is that from which delicious soups are made. In the inland aquatic species the toes are webbed.

CROCODILIA.

The Alligator. — Among the highest of the reptiles is the *alligator*. Living in swamps and stagnant pools in our Southern States, kept in most museums and zoölogical gardens, and when young often brought North by tourists as a pet, it is a form familiar to most Americans.

It resembles the lizard somewhat in form, but is from ten to twelve feet in length, and its body is covered with large, bony, epidermal plates. It differs from lower forms in having a four-chambered heart, two ventricles being present. It also has a better-developed brain. The eyes are protected not only by two lids, but, like the turtle's,

by a nictitating membrane. The centra of the vertebræ are concave in front, and convex behind. The feet are

FIG. 152.—ALLIGATOR.

well developed, the toes clawed, and partly webbed to fit it for its amphibious life. For the same reason the nostrils and external ears can be closed by valve-like arrangements. The teeth are conical, and set in sockets in the jaws. The alligator feeds principally on fish, but is also fond of aquatic birds and mammals, capturing and holding them below water until they drown. Then it comes to the

FIG. 153.—ALLIGATOR JUST HATCHED.

surface to devour its prey. Its throat can be closed to prevent water entering the pharynx when the mouth is open to capture its prey, or to hold it while it is drowning.

The reproduction is by eggs, which are laid in the sand, and hatched by the heat of the sun. The young, when out, quickly seek the water.

Other Crocodilia. — Related to the alligators are the crocodiles, which inhabit the streams and swamps in various tropical countries. One species is found in southern Florida. Both crocodiles and alligators love to lie basking in the sun, but are very active in the water. They hibernate in the mud.

General Characteristics of Reptiles. — Breathing throughout life by lungs; no metamorphosis; heart with three chambers in lower, and four in higher, members of the class; blood cold; body protected by epidermal scales or plates; reproduction in most forms by eggs, which are large, with limy shells; in a few families the young are produced alive.

CLASSIFICATION.

(*Class.*)	(*Order.*)	(*Examples.*)
Reptilia	Ophidia . . .	Garter snake, rattlesnake.
	Lacertia . . .	Pine-tree lizard, Anolis, horned toad.
	Testudinata . .	Box tortoise, marine turtle.
	Crocodilia . .	Alligator.

Books for Reference.

Kingsley's Standard Natural History.
Needham's Lessons in Zoölogy.
J. Ainsworth Davis's Text-Book of Zoölogy.
Nicholson's Manual of Zoölogy.

AVES, OR BIRDS.

The Pigeon. — The class of *birds* may be illustrated by the *pigeon*, which can easily be obtained for study. Most of what is said will, however, apply as well to the sparrow or any other small bird. A bird is distinguished from all other animals by its peculiar body covering of feathers, and by the development of the fore limbs as wings.

FIG. 154. — ROCK PIGEON.

Its skeleton presents some peculiarities. The skull of the adult bird is consolidated into a complete case for the brain, and it articulates with the atlas by a single *occipital condyle*. The lower jaw is joined to the skull by the quadrate bones, and both jaws are incased in horny beaks, which are toothless. The neck vertebræ are twelve in number (though the number varies in different birds), and articulate in such a way as to give very free movement, the centrum of each vertebra being saddle-shaped. The dorsal vertebræ are fused together in all flying birds. Beyond these comes the sacrum, to which the pelvic arch is

attached; and beyond come a number of free caudal vertebræ, ending with a piece which, from its shape, is called the plowshare. This bone and the sacrum each consist of a number of vertebræ fused together. The shoulder girdle consists of a pair of shoulder blades

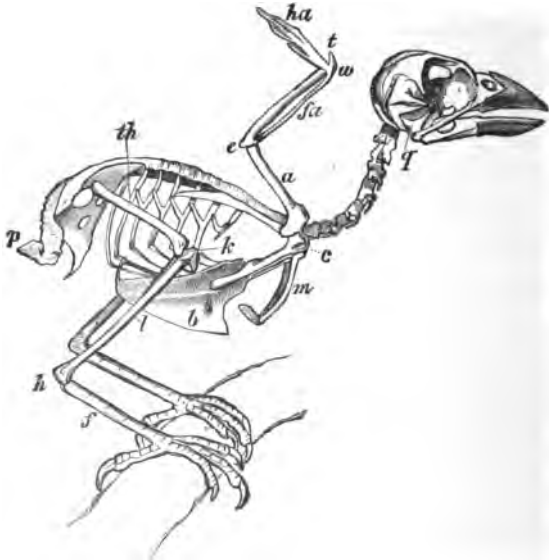

FIG. 155. — SKELETON OF A SPARROW: *q*, quadrate bone, peculiar to reptiles and birds, and some amphibians; *b*, breast bone; *m*, merrythought or collar bone; *c*, coracoid bone, over which the tendon works to pull up the wing; *p*, plowshare bone, on which the tail grows. Wing bones: *a*, upper arm; *e*, elbow; *fa*, forearm; *w*, wrist; *t*, thumb; *ha*, hand. Leg bones: *th*, thigh bone; *k*, knee; *l*, lower part of leg; *h*, heel; *f*, foot.

(scapulas), a pair of coracoid bones, and the collar bones (clavicles), which last are united to form the wishbone, luckybone, or merrythought. The ribs are firmly united to the immovable vertebræ behind, and to the sternum in front. The sternum is keeled, that the bird's breast

may be best adapted for cutting the air in flight. The bones of the wing are homologous with those of the human arm, and the leg bones with those of the human leg. The hand and foot are not so well developed. There are only two hand bones and three fingers. The foot, or tarsus, consists of one piece, and there are four toes present. The skull and long bones of the bird, instead of containing marrow, have air cavities, so that the skeleton is extremely light.

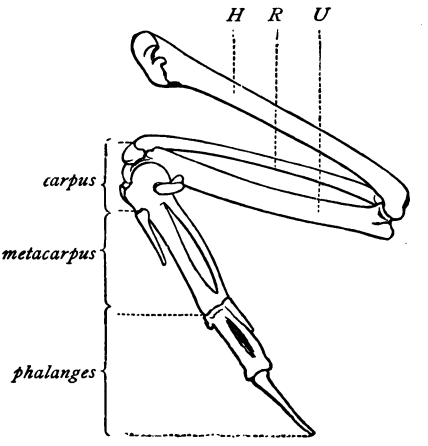

FIG. 156.—RIGHT WING OF AN ADULT BIRD SEEN FROM THE INSIDE: *H*, humerus; *R*, radius; *U*, ulna.

The external features are distinctive. The nostrils are slits near the base of the upper mandible, and are protected in the pigeon by a soft swollen membrane. Each eye is located in an orbit, and protected by two lids and also by a nictitating membrane. The opening to each external ear is behind the eye, and protected by feathers. Just above the tail is the opening of the duct from the oil gland. By means of the secretion from this gland, the feathers are kept smooth and glossy.

The wing, when not spread for flight, is doubled up along the side of the body. The bend of the wing corre-

sponds to the wrist of man. Upon the hand are located the ten *primaries*, or principal pinion feathers. To the forearm are attached the *secondaries*. The smaller overlapping feathers are called *wing coverts*. The long tail feathers are twelve in number, and are overlapped by *tail coverts*. The other feathers upon the body are called *contour feathers*.

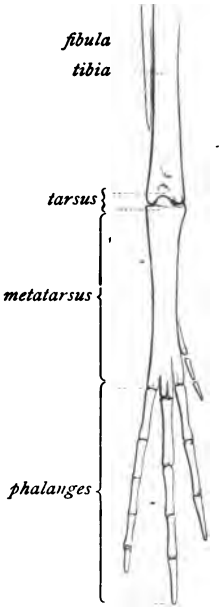

FIG. 157.—BONES OF THE RIGHT LEG OF AN ADULT BIRD. Only the lower portion of the tibia and fibula is drawn.

The feathers are developed from the epidermis, and are each located like the human hair upon a papilla of the true skin, at the base of a pit or follicle, out of which the feather grows. A feather consists of the following parts: the lower part of the central stem is a hollow *quill;* the outer part, which is solid, having within a pithy substance, is called the *shaft*. The shaft forms the center of the *vane*, and bears the *barbs*, which extend out on either side. Each barb, in turn, bears *barbules* along its sides. The barbules are provided with hooklets, which serve to hold the barbules on one side of one barb to those of the nearer side of the next. A feather with soft, free barbs is called *down*.

The bird's foot is peculiar. Only the toes are placed

upon the ground, the heel being raised considerably. The foot, which is unfeathered, is covered by scales; those in the pigeon overlap in front, but form a network behind. The toes are arranged, three in front and one behind (3—1), and the hind toe is on a level with the rest. The leg and foot of the bird are arranged to enable it to sleep

FIG. 158. — PARTS OF A FEATHER: 1, quill; 2, shaft; 3, vane or barbs.

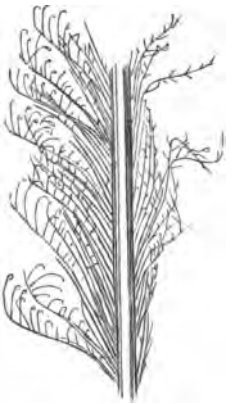

FIG. 159. — BARB FROM A GOOSE QUILL, SHOWING THE HOOKLETS HIGHLY MAGNIFIED.

perching. The muscles which move the toes are in the leg, and their tendons pass down outside the knee and ankle and under the toes; so that the weight of the bird, bending the knee and ankle joints, tightens the toes upon the perch.

Most birds feed upon grain or insects, though a few are carnivorous. The pigeon is a grain eater. The alimentary canal consists of mouth, pharynx, esophagus, crop,

stomach, gizzard, and intestines. The esophagus is very long. The crop is bilobed, and is used as a receptacle in which to store up food. The gizzard has a horny lining; and this, assisted by the gravel which the bird swallows, grinds up the food, which is not masticated in the mouth owing to the absence of teeth. The accessory digestive organs are the pancreas and liver, whose secretions are poured into the intestines. Gastric and intestinal juices are also supplied.

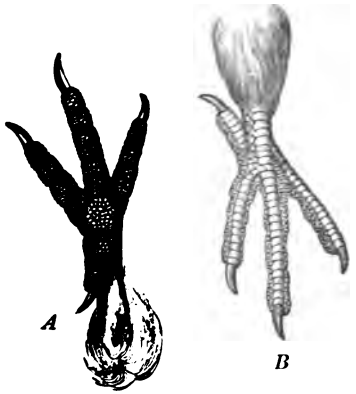

FIG. 160. — *A*, under view of the foot of the wood pigeon; *B*, upper view.

Digested food is absorbed by both blood vessels and lacteals. A small spleen is present.

The heart of the bird has four chambers, and both blood and lymph circulations are well developed. The blood is red and warm. The red corpuscles are oval and nucleated. The temperature of the bird's body is higher than that of any other animal, being 103° to 104° Fahrenheit.

FIG. 161. — SCUTELLATE TARSUS OF THE PIGEON.

The bird breathes by lungs. The air passes through the nostrils into the mouth, by means of the glottis into the larynx, thence into the trachea and into its two

divisions the bronchi, thence through branches into the lungs. Closely connected with the lungs are several air sacs, and these in turn communicate with the air cavities

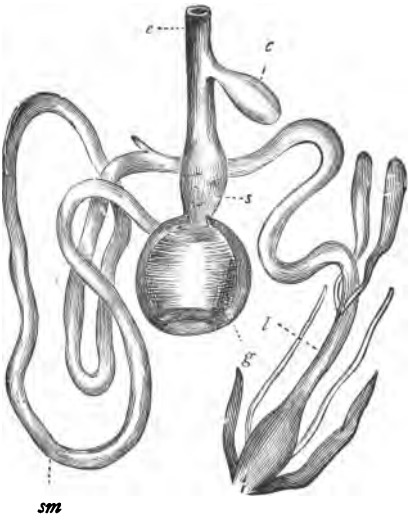

FIG. 162. — DIGESTIVE SYSTEM OF THE COMMON FOWL: *e*, esophagus; *c*, crop; *s*, stomach; *g*, gizzard; *sm*, small intestine; *l*, large intestine.

in the bones. The bird possesses no diaphragm. Its breathing is effected by a movement of the body walls. The vocal organs of the bird, instead of being in the larynx, are found just at the point where the bronchi separate.

The brain of the bird is better developed than that of any animal thus far described. The cerebrum is quite large, but has no

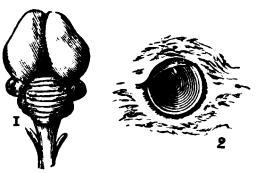

FIG. 163. — 1, Brain of a bird; 2, eye, showing nictitating membrane.

convolutions. The cerebellum is also relatively large. The special senses are all well developed, especially sight.

The reproduction of the bird is by means of eggs, which are relatively large, and possess limy shells.

At the close of the breeding season, birds molt, the new feathers having, of course, their brightest colors.

The pigeon is bred from the rock dove, and many different breeds have been obtained. The dove is distinguished by its small round head, rather short beak, and the iridescence of the neck plumage of the male.

The principal classification of keel-breasted birds depends upon external features. The character and shape of the beak; the relative length of body, wings, and tail; the character of foot and toes; the color and marking of the plumage, etc., — serve to identify the bird. Like other animals, it owes its variations to the result of adaptation to environment. The beak varies in shape and structure according to its food, and the manner in which that is obtained. Upon this also depend differences in the digestive apparatus. The wings are long or short, according to the habits of flight. The foot is modified, also, to accord with the use made of it.

Birds vary in their nesting habits. The greater number nest in bushes or trees; but even these show great differences in the structure of the nest, and the manner in which it is placed. Some nest on the ground. A few birds lay their eggs in the nests of others. The eggs of birds are usually incubated by the female; but among the song birds, and in a few other instances, the males divide the labor.

As a rule, male birds have the brightest plumage; and

in song birds the song of the male far excels that of the female.

Notes. 1. **The Ostrich.** — Among the lowest forms of birds are those which never leave the ground, and have therefore flat

FIG. 164. — WILD DUCKS.

sternums and poorly developed wings and tail, the legs being powerful. They are all large birds. The *ostrich* is an example.

2. **The Duck.** — The foot of the *duck* has a webbing between the three front toes, and is placed far back to aid it in swimming. The hind toe is small and elevated. The duck's feathers are very close and oily, that the body may be protected from the water. The bill is spatulate, or spoon-shaped, has a de-

FIG. 165. — FOOT OF A GANNET.

curved nail at the tip, and above this a very sensitive membrane. This enables the duck to feel about in the mud for food. The

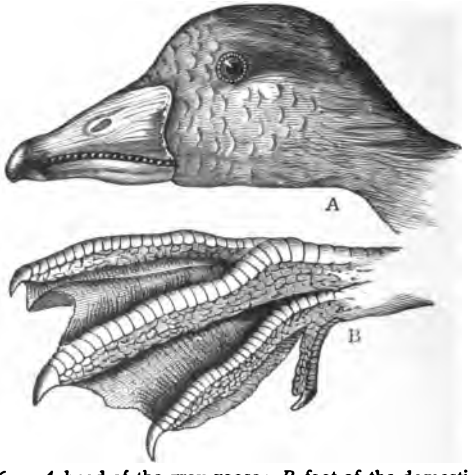

FIG. 166. — *A*, head of the gray goose; *B*, foot of the domestic goose.

cutting edges of each mandible are furnished with a series of tooth-like processes, which act as a strainer. To the order of the ducks belong also *geese* and *swans*.

FIG. 167. — FOOT OF A DUCK (ADAPTED FOR SWIMMING).

3. **The Hawk** has a foot whose four toes are well developed, with claws very large, sharp, and strong, and with the outer toe versatile; that is, it can be reversed, and turned so that the toes are opposed two to two (2 — 2). This foot enables the hawk to grasp, carry, and tear large and live prey. The bill is adapted for the same purpose, being large and

strongly hooked, and having a cered base, i.e., provided with a waxy membrane above the nostrils. The *owl*, another member of the order *Raptores* (or birds of prey), has very soft plumage, that its flight may be noiseless. The eyes are large and directed forwards, and best adapted for seeing at night, at which time the owl secures its prey. The other members of this order are the *eagles*, *falcons*, *buzzards*, *vultures*, and *kites*.

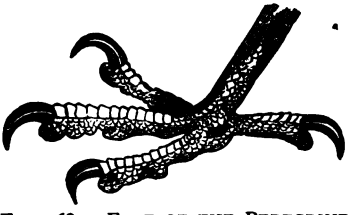

FIG. 168.— FOOT OF THE PEREGRINE FALCON.

4. **The Woodpecker** has a stout, tapering bill, with the tip either truncate or acute in different species, but always adapted for boring into wood. The tongue is long, barbed, and capable of being protruded into the hole, to secure the larvæ upon which the woodpecker feeds. The toes are 2 — 2. This is the best arrangement for climbing. The tail feathers are rigid and acute at the outer end, and assist in bracing the body. This bird is a most valuable one, destroying the larvæ of many insects injurious to vegetation.

FIG. 169.— TONGUE OF WOODPECKER.

5. **The Humming Bird** has a long, slender bill for getting the honey from deep corollas. Its tongue is long, and capable of great protrusion. The wings are long and pointed, and move so rapidly as to keep the bird suspended for some length of time above the blossom from which it is drawing sweets. The feet are weak, the hind toe small and elevated. The common humming bird of our country is the *ruby-throated*, whose plumage is metallic green, with ruby throat and purple tail.

6. **The Whip-poor-will**, whose mournful cry has given it its name, is an insectivorous bird, and flies usually at dusk and dawn, capturing insects on the wing. Its bill is triangular, short, and wide,

with very wide gape, and with bristles at the corners of the mouth (rictus). This structure of its beak enables it to secure its prey. The wings are long and pointed. Belonging to the same family is the *night hawk* or *bull bat.*

FIG. 170. — CLAW OF DOMESTIC FOWL, SCRATCHING.

7. **The Quail,** *partridge,* or *bobwhite,* has a foot adapted for scratching. The toes are slightly webbed at the base, and the hind toe is small and elevated. The bill is stout and convex. Belonging to the same order of the *scratching birds* are our introduced barnyard fowls — the common *chicken, guinea fowl, peacock,* etc. — and the following native birds, — the *turkey, grouse, prairie hen,* and *pheasant.*

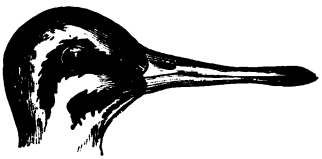

FIG. 171. — HEAD OF THE SNIPE.

8. **The Snipe,** being a wader, has long legs and a foot with the hind toe elevated. It has a very long bill, which is flexible and

sensitive, and blunt at the tip, fitted for probing in the mud. Related to the snipe are other waders, such as the *plover*, *woodcock*, *sandpiper*, etc. Closely related to these, but separated by some authorities into another order, are the *herons* and *bitterns*. These differ in the structure of the bill, which is straight, acute, and not sensitive. The neck is very much longer. Still another order closely related contains the *cranes* and *rails*, and the curious *coot* or *mud hen*.

FIG. 172. — CRANE.

9. **The Pelican** is a large, fish-eating bird, with a long, stout bill ending in a hook. A large membranous pouch beneath the bill is used for storing the food. The foot of the pelican is peculiar, being

FIG. 173. — BROWN PELICAN.

fully webbed, with the hind toe included in the webbing. The wings are very long, and the tail short. Related is the *cormorant.*

FIG. 174. — COMMON HERON.

10. **The Gull** is a bird with very long wings and well-developed tail, giving it remarkable powers of flight. The foot is palmate; that is, three toes are webbed. The hind toe is small and elevated. The bill is long. The bird feeds upon fishes. Related are the *jagers*, *terns*, *petrels*, and *albatrosses*.

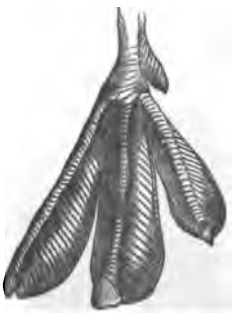

FIG. 175. — FOOT OF GREBE, SHOWING SWIMMING MEMBRANE ON EACH TOE.

11. **The Loon** is a noted diver. Its feet are palmate, and set far back. The wings are long and strong. The bill is long,

strong, tapering, and acute. The *grebe*, which is closely related, has short wings, a slender bill, and the foot *lobate*, the membranous webbing being separate upon each toe.

12. Song Birds. — The perching or song birds are the best represented in the number of families, genera, and species. They are comparatively small, have rather conical bills, and a foot adapted for perching by having the hind toe long and not elevated, and long, curved claws adapted for grasping the perch. The tarsus is scutellate, the scales on the front overlapping like shingles on a roof. The back of the tarsus has a sharp ridge. The vocal organ is well developed.

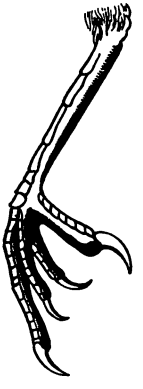

FIG. 176. — SCUTELLATE TARSUS OF SONG BIRD.

13. The Sparrow. — The family of the *sparrows* (*Fringillidæ*) is well represented, including those birds with stout, truly conical bills, with the corners of the mouth drawn down or abruptly angulated. It includes, besides many *sparrows* and *finches*, the *redbird* or *cardinal grosbeak*, the *indigo bird*, the *buntings*, the *goldfinch* or *pine linnet*, and the *yellowbird* or *thistle bird*. The *canary* belongs to this family.

14. The Thrush has a long, not very conical bill, with bristles at the rictus, and the tarsus "booted," the scutellæ having fused to form a continuous plate. Besides several species of *thrushes*, the *robin*, *mocking bird*, and *catbird* all belong to this family (*Turdidæ*). All are exquisite songsters. Belonging to another family having almost the same characteristics, except for more brilliant coloring, are the *bluebirds*.

15. The Warbler. — One of the largest American families is that of the *warblers* (*Sylviicolidæ*). They are very small birds, never much over six inches in length, and most of them less than five. They are insectivorous and migratory, and live in tree tops. They are fair singers, and many have brilliant plumage.

16. **The Swallow.** — The family of the *swallows* (*Hirundinidæ*) embraces birds with broad, short, depressed, triangular bills, with very long, pointed wings, and forked tail, and with weak feet. All are insectivorous and migratory, and noted for their long and rapid flight.

17. **The Oriole.** — The family of the *orioles*, etc. (*Icteridæ*), consists of birds whose bills somewhat resemble those of the sparrows, being more lengthened, and having the base of the upper mandible, extending up on the forehead, dividing the frontal feathers. The head is not so rounded as in the sparrows. The plumage is usually lustrous, and in some species brightly colored. To this family belong the *orioles*, *bobolink*, *cowbird*, *meadow larks*, and several species of *blackbirds*.

18. **The Crow.** — The family of the *crow* (*Corvidæ*) includes also the *raven*, *magpie*, and *jays*. They have long, strong bills, and are large birds with harsh voices. They are grain eaters.

19. **The Flycatcher.** — The family of the *flycatchers* (*Tyrannidæ*) includes insectivorous birds, with broad, triangular, depressed bills, hooked and notched at the tip, with long bristles at the rictus, and very wide gape. They are migratory. The family includes the *kingbird* or *bee martin*, *pewees*, and several other flycatchers.

20. **Other Birds.** — There are several other families of birds which in the United States are represented by one or more species. Such are the *wrens*, *larks*, *shrikes* or *butcher birds*, *kinglets*, *waxwings*, *tanagers*, and *vireos*, of the song birds; and the *kingfisher*, *paroquet*, and *chimney swallow*, of the same order with the *woodpeckers*.

General Characteristics. — Blood warm; body feathered; fore limbs developed as wings; one occipital condyle; mouth a horny beak; heart with four cavities; breathing by lungs; no diaphragm; reproduction by eggs; in the flying birds, a keeled sternum, bones hollow.

Classification.

(*Class.*)	(*Subclass.*)	(*Order.*)	(*Examples.*)
Aves.	Keel-breasted, or Carinata.	Pygopodes	Loons, grebes, auks.
		Longipennes	Gulls, terns.
		Steganopodes	Pelicans, cormorant.
		Lamellirostres	Ducks, geese, swans.
		Alectorides	Rails, coot.
		Herodiones	Herons, bitterns.
		Limicolæ	Plovers, snipes, sandpipers, curlews.
		Gallinæ	Quails, chickens, turkeys, pheasants, etc.
		Columbæ	Pigeons, doves.
		Raptores	Hawks, owls, buzzards, vultures.
		Psittaci	Parrots, paroquets.
		Picariæ	Woodpeckers, cuckoo, kingfisher, swift, night hawk, whip-poor-will, humming bird.
		Passeres	

(*Suborder.*)	(*Examples.*)
1. Turdidæ	Thrush, Mocking bird, Catbird, Robin.
2. Saxicolidæ	Bluebirds.
3. Sylviidæ	Kinglets.
4. Paridæ	Titmice.
5. Sittidæ	Nuthatches.
6. Certhiidæ	Creepers.
7. Troglodytidæ	Wrens.
8. Alaudidæ	Larks.
9. Motacillidæ	Wagtails.
10. Sylviicolidæ	Warblers.
11. Tanagridæ	Tanagers.
12. Hirundinidæ	Swallows.
13. Ampelidæ	Waxwings.
14. Vireonidæ	Vireos.
15. Laniidæ	Shrikes.
16. Fringillidæ	Sparrows, Redbird, Indigo bird, Canary, Buntings.
17. Corvidæ	Raven, crow, Bluejays.
18. Tyrannidæ	Flycatchers.

Books for Reference.

Kingsley's Standard Natural History.
Coues's Key to North American Birds.
Davis's Text-Book of Zoölogy.
Jordan's Manual of Vertebrates.

Instructions for Skinning, and Preparing Bird Skins.

A good bird to begin with is one the size of a quail. After a bird is killed, the sooner it is skinned the better, as the skin becomes tender, and tears easily if kept too long.

The tools necessary are a pair of *sharp-pointed scissors*, a pair of *spring forceps*, and a small *scalpel*. *Cotton* is needed for stuffing the body. *Powdered arsenic* is needed for preserving the skin from insect pests. Pulverized *plaster of Paris* is needed for drying moist secretions, and for removing blood stains.

See first that the hands are free from cuts or scratches, as arsenic introduced into the circulation will produce blood poisoning.

To measure your bird, lay it on its back, and get the length from the tip of the beak to the tip of the tail. Measure the tail from the joint with the body to its tip. Measure the wing from the bend or wrist joint to the tip.

To remove blood stains, wash gently with a sponge and a little warm water, and dry with plaster of Paris. Then open the mouth and insert a piece of cotton into the throat. Take a needle and stout thread, and pass the needle across from one nostril to the other, drawing the thread through. Tie the thread about the beak to hold it closed, and leave the ends about four inches in length. Next break the wing bones close to the body.

Lay the bird on its back, blow back the feathers from the middle line of the abdomen, where a bare place will be seen. Stroke back the feathers from this, and, lifting the skin at the end of the sternum, insert the point of the scissors, and cut down along the middle line of the abdomen to the anus, being careful not to cut through into the abdomen itself. Then with the scalpel separate the skin from the body wall by gently pushing the body

away from the skin. Keep stroking the feathers away from the cut, and dry all the exposed parts of the body with plaster of Paris. Push the skin loose all around the thigh. With the scissors cut off the leg close to the body. Then pull the leg out of the skin as far as possible, cut the ligaments, and clean the muscles off the leg bones. Draw the leg back into its skin. Repeat this with the other leg. Loosen the skin around the tail. The fingers may be used to assist in this. Insert the scissors and cut through the backbone at the tail, leaving the coccyx to support the tail feathers. Having loosened the lower part of the body, take the bird up, and work the skin loose to the wings. Clean the wing bones in the same manner as those of the legs, removing the humerus. Then, having loosened the skin to the base of the skull, turn it back carefully over the head. With the thumb nail, carefully loosen the skin over the ear. Cut the thin membrane which holds the skin at the eye, being careful not to cut the true eyelid. This frees the skin to the beaks. Loosen and lift out the eyes. Cut out the base of the skull, removing the flesh between the jaws, and also the brain. The whole body will then be free.

Powder the reversed skin, and the skull, wing, and leg bones, with arsenic. Put a little ball of cotton into each eye socket. If a large bird, wrap the thigh bones with a little cotton. Turn the skin right side out, drawing up the beak by the ends of thread which were tied about it. In turning the skin over the head, push it back very gradually.

Mold a piece of cotton to the size of the bird's body. With the forceps insert one end of this into the skull, filling the skin. Then bring the cut edges of skin over the abdomen together, and stroke the feathers back, to conceal the cut. Stroke down the ruffled feathers, bringing head, wings, and tail into as easy and proper positions as possible. Cross the feet, and tie them. Make a cornucopia of paper, and put the bird, head downwards, into this to dry, being careful first to dust off any arsenic on the feathers.

Carefully wash the hands and all tools used. The work should be done over a large paper, which can be gathered up and disposed

of. Label the bird with a tag attached to the feet, giving genus, and species, and common name; also sex, and date and place of collection.

MAMMALIA.

The Rabbit. — One typical form among the mammals is the *rabbit*. The wild and tame ones differ little in essential features. The body is bilaterally symmetrical, with limbs adapted for running and leaping, and a short but distinct tail. The body covering is hair. This is developed like the human hair from the epidermis, and its root is located in a follicle, at the bottom of which is a papilla. The hairs are continually being shed and replaced by new ones.

The head is long, and tapers towards the snout. The mouth, as in other vertebrates, opens transversely, the lips being soft and mobile, and the upper lip cleft. The nostrils are slits near the tip of the snout. Long, stiff hairs or whiskers are present on the sides of the snout. The eyes are protected by two eyelids with stiff lashes, and also by an opaque membrane. Each auditory aperture is far back, and is guarded by a long, backwardly and upwardly directed ear, whose base is supported by cartilage.

The skull is bony, and the sutures are distinct in the adult. The vertebræ are divided into cervical or neck (of which there are always seven in the mammal); dorsal or back, twelve in number; lumbar, seven in number; a sacrum; and fifteen caudal vertebræ. The dorsal, lumbar, and caudal vertebræ vary in number in different mammals. The ribs are twelve pairs, articulate dorsally with

the dorsal vertebræ, and are attached ventrally to the sternum. Seven pairs have a direct attachment, the others do not.

The shoulder girdle consists of clavicle and scapula. The arm bones are the humerus in the upper, in the lower the ulna and radius, which are immovably articulated in the position which the human forearm takes when the hand is laid palm down. The carpal bones are present, as are also hand and finger bones, in the same number and arrangement as in the human hand. The terminal phalanges support claws.

The hip girdle consists of the two innominate bones. The leg bones are the femur, tibia, and fibula. The foot consists of tarsal and metatarsal bones. There are only four toes, the one corresponding to the great toe being wanting.

The mouth cavity is elongated. Into its roof open two nasal passages. The teeth are imbedded in sockets in the jaws. The first or milk teeth are soon lost, and replaced by permanent ones. These grow throughout life, as they are worn away at their tips. In the front of each jaw are two incisors, which are chisel-like, having enamel only in front. This causes them to wear so as to keep a sharp cutting edge. The upper jaw has another pair of very small and sharp incisors, which are placed a little back from the edge of the jaw, just outside of the first pair. The canine teeth are wanting in both jaws;

FIG. 177.—SKULL OF A GNAWING ANIMAL, SHOWING THE LARGE CHISEL TEETH IN FRONT, AND THE GAP BETWEEN THESE AND THE HIND TEETH.

but the molars or grinders number six pairs above, and five below. These teeth are adapted for gnawing. The jaws work backward and forward. The food is entirely vegetable.

The alimentary canal consists of the same parts as in man. Into the mouth is poured the saliva. Back of the mouth is the pharynx, into which opens a single nasal passage and the two Eustachian tubes. The openings downward are the glottis, guarded by an epiglottis, and that into the esophagus. The esophagus passes through the diaphragm, and connects with the stomach, which in turn empties its contents into the much-winding small intestines. The large intestine completes the alimentary canal. The structure of each of these organs resembles that of the corresponding organs in man. The other accessory organs are liver and pancreas. The secretions of the liver and pancreas enter the duodenum, but not together, as they do in man. The diaphragm is present in mammals.

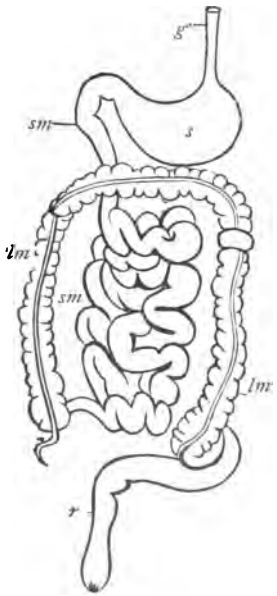

FIG. 178. — DIGESTIVE SYSTEM OF A MAMMAL: *g*, gullet or esophagus; *s*, stomach; *sm*, small intestine; *lm*, large intestine; *r*, large intestine, terminating in rectum.

The heart of the rabbit is conical and four-chambered. The blood is red and warm, the red corpuscles being flat,

circular disks, not nucleated. The lymphatic system is well developed. The lacteals begin in the villi, and absorb fatty foods. A spleen is present, located to the left, and a little behind the stomach.

The breathing of the rabbit is by lungs, and is similar to that of man.

The brain of the rabbit is elongated, and not very well developed. The special senses are keen.

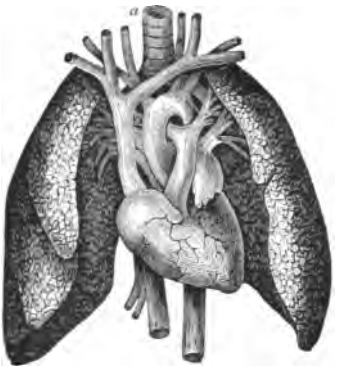

FIG. 179. — HEART AND LUNGS: *a*, windpipe.

In mammals, as in other animals, the structure of the body is adapted to the habits of the animal and its environment. The rabbit is a typical gnawing animal.

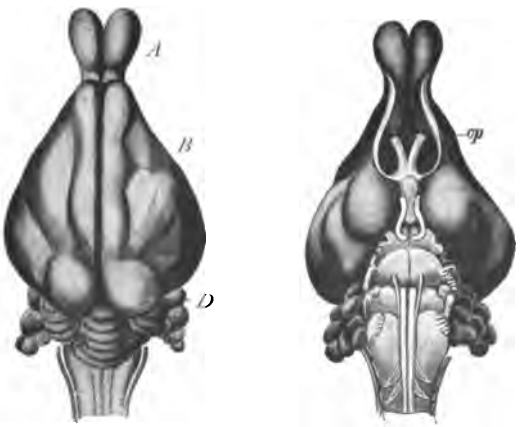

FIG. 180. — BRAIN OF A RABBIT (upper surface on the right, lower on the left): *A*, olfactive lobes; *B*, cerebral hemispheres; *D*, cerebellum; *op*, optic nerve.

Other Gnawing Mammals. — Belonging to the same order with the rabbits and hares, are *squirrels, rats, mice, beavers, muskrats,* etc.

The Red Deer. — Of the grazing mammals, the *red deer* is a type. The external features present some peculiarities. The body covering is hair, which lies close to the skin. The head is surmounted by a pair of solid branching horns, which are outgrowths of the frontal bones. These are at first covered with soft skin, which, however, soon wears off. They are present only in the male, and are shed and renewed every year. The foot has only two toes developed, and the toe bones are covered with horny hoofs.

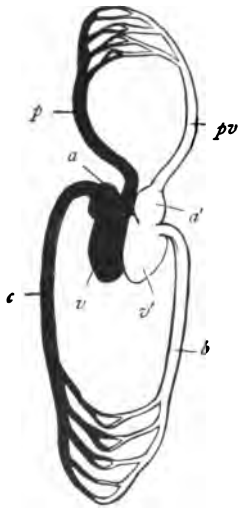

FIG. 181. — DIAGRAM OF THE CIRCULATION IN A MAMMAL. The cavities containing venous blood are marked black, those containing arterial blood are left white: *a*, right auricle; *v*, right ventricle; *p*, pulmonary artery, carrying venous blood to the lungs; *pv*, pulmonary veins, carrying arterial blood from the lungs; *a'*, left auricle; *v'*, left ventricle; *b*, aorta, carrying arterial blood to the body; *c*, vena cava, carrying venous blood to the heart.

The digestive apparatus is peculiar. The incisor teeth are absent in the upper jaw, which has instead a hard pad. The incisors and canines of the lower jaw are pressed against this pad in breaking or tearing off the mouthful of grass or other herbage upon which the deer feeds. The molar teeth, six pairs in each jaw, are large, with

flat surfaces upon which are crescentic ridges of enamel. The food, being drawn into the mouth with the long tongue and nipped off, is mixed with saliva and swallowed without mastication. It passes down the esophagus and through a valve-like opening into a *paunch*, where it is further moistened. The paunch connects, by a free opening, with a *honeycomb*, or *reticulum*, whose interior is divided into polygonal cells. The moistened food here is molded into pellets. After the animal has satisfied his appetite, he lies down to chew the cud. The pellets of food are regurgitated one by one, by sudden contractions of abdominal muscles and diaphragm. As each pellet reaches the mouth, it is thoroughly masticated, and swallowed a second time. The soft mass, being unable to push open the valve and enter the paunch, passes on into a third compartment, the *many-*

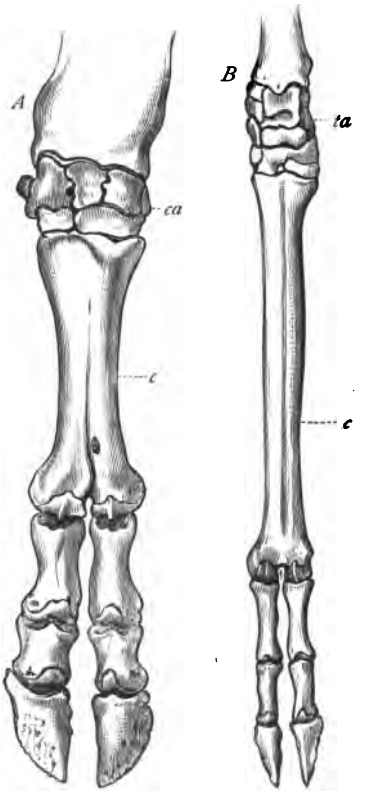

FIG. 182. — *A*, fore leg of ox (*Bos taurus*); *B*, hind leg of stag (*Cervus elaphus*): *ca*, carpus; *ta*, tarsus; *c*, canon bone, composed of the united metacarpals or metatarsals of the third and fourth digits.

plies. This has its lining raised into folds resembling leaves in a book, and acts as a strainer. The fourth or true stomach secretes the gastric juice or *rennet,* which

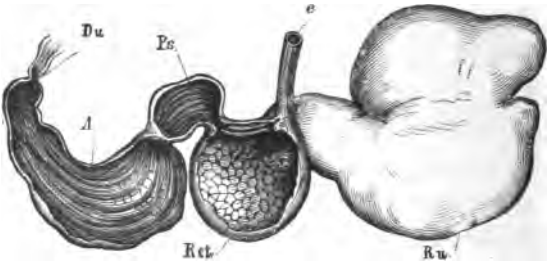

FIG. 183. — STOMACH OF A SHEEP: *e*, esophagus; *Ru*, paunch; *Ret*, honeycomb; *Ps*, manyplies; *A*, true digestive stomach or rennet; *Du*, beginning of intestine.

digests the proteid foods. The other digestive organs are like those of man.

Other Grazing Mammals. — Belonging to the same suborder with the *deer, moose* or *elk,* and *wapiti,* are the family of the *camel,* and that of the hollow-horned ruminants, which includes *buffalo* and *bison, antelopes, sheep, goats,* and domestic *cattle.* This latter family differs from that of the deer in having persistent hollow horns present in both sexes, and in having the canine teeth lacking in the upper jaw, as well as the incisors.

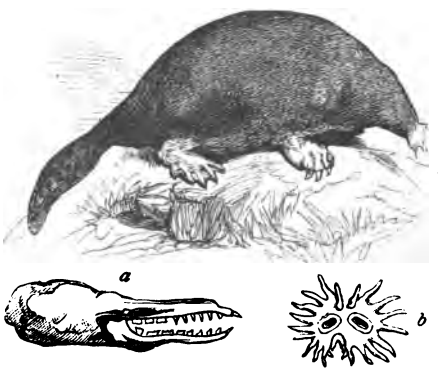

FIG. 184. — STAR-NOSED MOLE (CONDYLURA CRISTATA): *a*, jaws; *b*, end of nose.

The Mole. — Of insectivorous animals, the *mole* is most common. The body

is stout without visible neck. The snout is long and tapering. The eyes are rudimentary, and there is no external ear. The fur is close and velvety. The limbs are very short, the fore limbs being thick and adapted for burrowing in the soil. The teeth are all present and are very sharp. Related to the moles are the *shrews*.

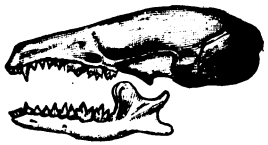

FIG. 185. — SKULL OF AN INSECT-EATING MAMMAL, SHOWING THE NUMEROUS POINTED TEETH.

The Bat. — A mammal very peculiar in external features is the *bat*. With a body resembling that of the mouse, its fore limbs are developed into wings. The forearm bones are elongated, and the four fingers are still more

FIG. 186. — SKELETON AND OUTLINE OF BAT.

prolonged to support a membranous webbing, which extends backwards to include the hind limbs and tail. The hind toes are free and clawed, as is also the thumb. The sternum is slightly keeled. The teeth are numerous, small, and sharp.

The Cat and other Carnivora. — Among the highest mammals are the *Carnivora*, which are represented in our country by the families of the *cat*, *dog*, *weasel*, *bear*, and *raccoon*. The *cat* is noted for its agility, its quiet movements, and its strength. Its feet are padded beneath, and are provided with retractile claws, the toes being five upon each fore foot, and four upon each hind one. The fifth toe is not opposable to the others.

FIG. 187. — FOOT OF THE LION.

The face is short and broad, and the muzzle short. Upon the face are whiskers, which are sensitive. The eyes are large, and the pupil contracts in a strong light to a vertical linear slit. The jaws are short and stout, and

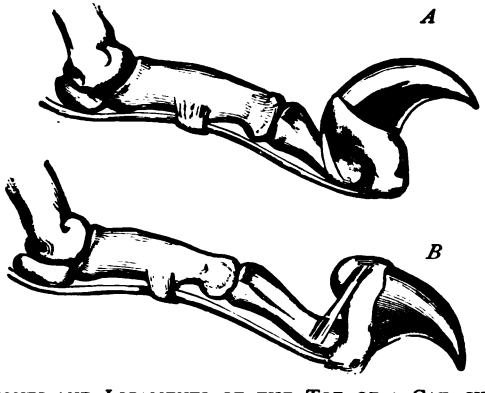

FIG. 188. — BONES AND LIGAMENTS OF THE TOE OF A CAT, SHOWING THE CLAW RETRACTED (*A*) AND PROTRUDED (*B*).

closely attached. All four sets of teeth are present, and they are adapted for cutting and tearing rather than for

grinding. The canines are enlarged into fangs. The tongue is very rough. There are thirteen dorsal vertebræ, and numerous caudal ones, the tail being long and strong.

FIG. 189. — SKULL OF THE LION (SIDE VIEW).

The domestic cat is descended from an Egyptian form. The members of the family native to North America are the *puma* (also called *panther* and *cougar*) and the *lynx*. Among foreign forms are the *lion, tiger, leopard, jaguar, ounce*, and the *wild cat*.

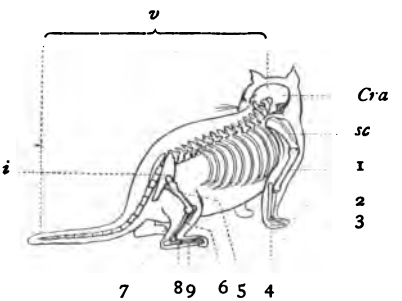

FIG. 190. — CAT WITH BONES OF RIGHT SIDE DRAWN: *Cra*, cranium; *sc*, scapula or shoulder blade; 1, humerus; 2, radius and ulna; 3, carpus; 4, phalanges; 5, femur; 6, tibia and fibula; 7, tarsus; 8, metatarsus; 9, phalanges; *i*, innominate bone, a number of bones combined, forming the pelvic arch; *v*, vertebral column.

The Higher Mammals. — The highest mammals, except man, are the tailless apes, — the *orang-outang*, the *chimpanzee*, and the *gorilla*. The chimpanzee is not so fierce as the others, and is more easily tamed. It measures about

five feet in height. It rarely, however, carries itself erect, usually stooping so that the arms hang with the knuckles touching the ground.

The face of the chimpanzee bears some resemblance to that of man, the skin being naked. The ears are larger, and the mouth and lips large and ugly. The rest of the head is covered with shiny black hair. Occasionally there is a beard of whitish hairs. The arms are very long in

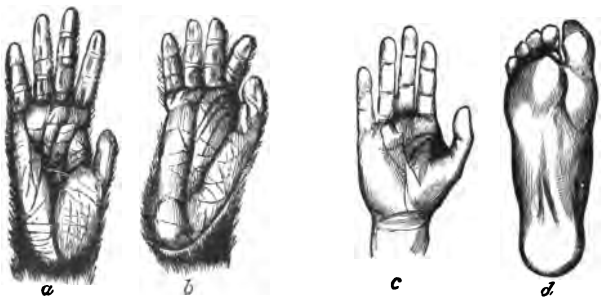

FIG. 191. — HAND (*a*) AND FOOT (*b*) OF CHIMPANZEE; HAND (*c*) AND FOOT (*d*) OF MAN.

proportion to the body; the fingers are short, and both the thumbs and the great toes are opposable to the other digits. The chimpanzee is an expert climber, living for a great part of the time in the trees, and feeding upon fruits.

The tailless apes differ from man in many respects. The backbone of man has a double curve, giving him an elastic step: this is not true in the apes. In man the measurement from finger tip to finger tip of the outstretched arm equals but rarely exceeds the height: in the apes it much exceeds. In man the face is relatively small in comparison with the skull, and the fore brain overhangs the face: in the apes the face is heavy and protruding, and the forehead

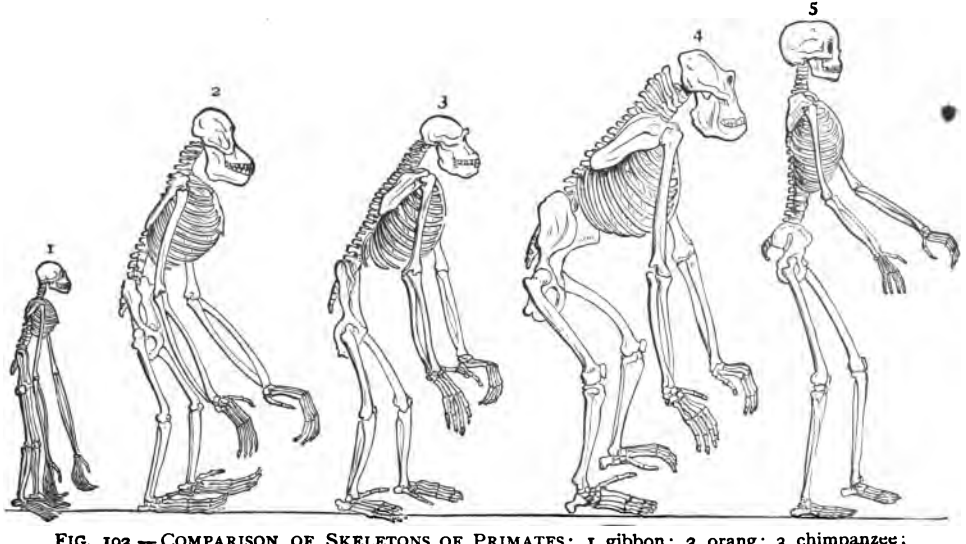

FIG. 192. — COMPARISON OF SKELETONS OF PRIMATES: 1, gibbon; 2, orang; 3, chimpanzee; 4, gorilla; 5, man.

retreating. The size of the brain in man is far in excess of that of the ape. Man alone possesses the power of

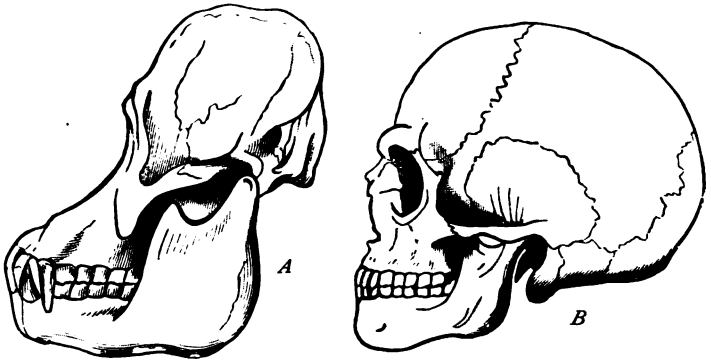

FIG. 193. — *A*, SKULL OF THE ORANG-OUTANG; *B*, SKULL OF A EUROPEAN ADULT.

speech. These are only a few of the most noticeable differences.

Notes. 1. **The Opossum.** — One native mammal very low in the scale of development is the *opossum*. This animal is not so large as a cat, and is arboreal and nocturnal in its habits. The feet are five-toed, and are clawed, except the great toe of each hind foot, which is opposable like a thumb, and clawless. The tail is long, is naked or scaled, and is prehensile. The rest of the body is covered with a woolly fur. The snout is very pointed. The animal, when attacked, feigns death.

FIG. 194. — THE OPOSSUM.

The young, being born in a very helpless condition, are carried by the mother for two months or more in a pouch provided for the purpose. This consists of a fold of skin, hairless on the inner side.

Related to the opossum are the foreign forms, — the *kangaroo* and the *wombat.*

2. The Sea Cow (or *manatee*) is a mammal whose life is spent mostly in the water. The fore limbs are paddle-like, and the hind limbs are wanting. It has a tail flattened horizontally. The sea cow is a grazing animal, living near shore, and its teeth are adapted for grinding.

3. The Whale is a fish-like mammal with paddle-like fore limbs, no hind limbs, and a forked tail horizontally flattened. Its skin is smooth, and just beneath it is a layer of fat or blubber, which protects the body from cold. The breathing orifices are called *blowholes,* and are on the top of the head. The whale does not eject water through these, but only the air from the lungs. The animal is enabled to remain for from ten to twenty

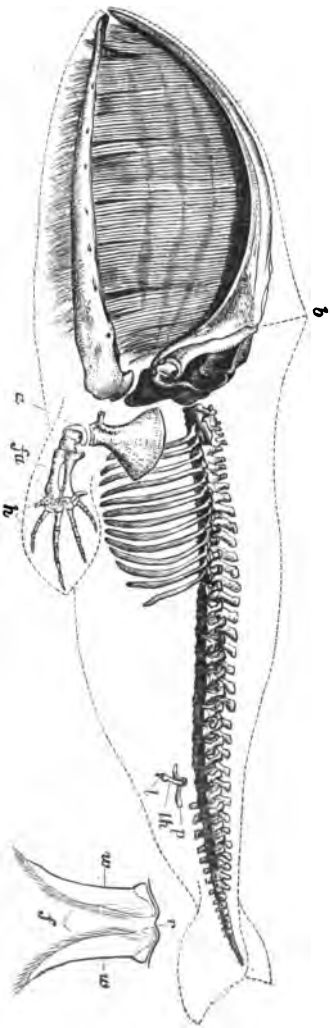

FIG. 195. — SKELETON OF A WHALEBONE WHALE, AND SECTION OF THE MOUTH WITH WHALEBONE: *b*, blowhole; *a*, upper arm; *fa*, forearm; *h*, hand; *p*, *th*, *l*, small remains of pelvis or hip bone, thigh, and leg; *r*, roof of the palate; *w*, plates of whalebone; *f*, whalebone fringe.

minutes below the surface of the water by having an extra supply of blood vessels, which act as reservoirs for extra pure and impure blood.

The whalebones of commerce are obtained from these animals. A whalebone whale has no teeth developed; but instead there hang from each side of the upper jaw a series of whalebone plates, arranged like saws in a rack. These plates are fringed on their inner edges, and are so close together as to act as a strainer. The whale feeds principally upon small crustaceans, mollusks, and jellyfishes, which are near the surface of the ocean. To capture these, it swims with open mouth, the lower lip resembling a scoop. Having secured a sufficient quantity, it raises its head out of the water, allowing the water in its mouth to escape between the plates at the side. Then with its tongue it gathers together the food, which must pass down an esophagus only two or three inches wide. After being below the surface ten or twenty minutes, the whale rises, and is from one minute and a half to two minutes and a half in oxygenating its blood, blowing out the air from six to nine times.

Related to the whalebone whales are the toothed whales, — the *dolphin*, *porpoise*, *narwhal*, *sperm whale*, etc.

4. **Rats and Mice.** — House *rats* and *mice*, which are universally distributed, are natives of the Eastern Hemisphere, having been carried in the holds of vessels into every known land.

5. **The Beaver** lives in and about the water: consequently its fur is short and close, the hind feet webbed, and the tail flattened, spoon-shaped, and scaly, and used to scull with. The beaver burrows in the banks of a stream. It builds dams, creating artificial lakes, which are its refuge when it is attacked. These dams consist of sticks, stones, and mud. The beaver can gnaw through the trunks of large trees, feeding upon the twigs and small branches, and using the larger ones in building its house and dams.

6. **Hoofed Mammals.** — Beside the cud-chewing mammals, there are many others whose toes are hoofed, the number of toes present varying in different families. Thus the *elephant* has five

toes upon each foot; only four of these, however, are externally hoofed. The *rhinoceros* has three toes hoofed. The *tapir* has three upon each hind foot, four upon each fore foot. The *hippopotamus* and the *wild boar*, with the domestic *pig*, are four-toed. The *horse* has but one toe hoofed.

7. **The Bear** is one of the most common of our American *Carnivora*. Its body is heavy and clumsy. The feet are *plantigrade*, the sole of the foot being placed flat upon the ground. The head has a long muzzle. The teeth are better adapted for grinding than in the cat or dog, and the lower jaw is more loosely attached. This corresponds with the difference in the food, the bear feeding usually on vegetables, insects, and honey, though some bears have a decided preference for flesh. Such is the *grizzly bear*. The *polar bear* is truly carnivorous.

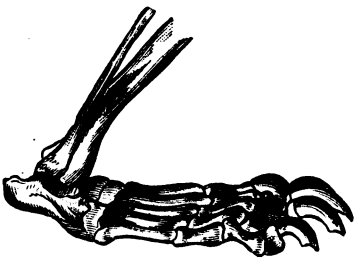

FIG. 196. — FOOT OF THE BEAR.

8. **The Raccoon** (or "coon," as it is familiarly called) is a small carnivorous animal with bear-like characteristics. It has a broad head and pointed muzzle, with rather large ears. Its feet, like those of the bear, are plantigrade in standing, but the animal walks only on its toes. The body is covered with long, loose hair, which hides a close fur. The raccoon feeds upon either animal or vegetable diet, being fond of frogs, birds, eggs, and especially of fish and oysters.

9. **The Weasel** is a small carnivorous animal with very long neck, slender body, and long tail. The animal walks only on its toes, which are five upon each foot, with retractile claws. It is very fierce and extremely active, and has a very keen scent. The animal is supplied with glands near the tail, which secrete a fluid whose odor is offensive.

Related are the *mink*, *ermine*, *wolverine*, *badger*, *sable* or *marten*, *skunk*, and *otter*.

10. The Dog differs from the cat in several respects. The muzzle is longer and more pointed, no whiskers being present. The toes are not retractile. The limbs are longer and better adapted for running. The scent is very keen.

Belonging to this family are not only dogs, but *foxes*, *wolves*, *jackals*, and *coyotes*.

11. The Seal, a carnivorous mammal whose life is spent in the water, has a close fur, and the limbs developed as paddles. Both pairs are set far back, and five toes are developed on each.

FIG. 197. — HIND FEET OF SEAL.

Related are the *sea bear*, *sea lion*, and *walrus*.

12. The Monkey. — Belonging to the primates are the monkeys, which are found in the Old World and in South America. The New-World monkey has a prehensile tail.

13. Hibernating Mammals. — Many mammals hibernate during the winter season. At this time the vital processes are almost entirely suspended, the animal subsisting on fat stored up for the purpose during the summer season.

General Characteristics. — Young born alive, and nourished at first with milk; body covering, hair; blood warm; heart with four cavities; breathing by lungs; chest separated from abdomen by diaphragm; lower jaw articulating directly with the skull; two occipital condyles.

Suggestions for Review. — Compare the rabbit with the perch in the structure of skeleton, of vital organs, and of nervous system, in the development of the special senses and in the reproduction. In the same way compare it with the frog, the lizard, and the pigeon. The points in which all these animals resemble each other will give the general characteristics of the vertebrates: their differences will show the principal class distinctions.

CLASSIFICATION.

(*Class.*)	(*Subclass.*)	(*Order.*)	(*Examples.*)
Mammalia.	Didelphia.		Opossum.
	Monodelphia.	Rodentia	Squirrels, rats, mice, beavers, rabbits, porcupines.
		Insectivora	Moles, shrews.
		Chiroptera	Bats.
		Cetacea	Whales.
		Sirenia	Sea cows.
		Proboscidea	Elephants.
		Ungulata	Hoofed mammals, such as the horse, camel, giraffe, tapir, rhinoceros, hippopotamus, ox, deer, sheep, goat, bison, etc.
		Carnivora	Seal, bear, raccoon, weasel, dog, cat, etc.
		Primates	Monkeys, apes, and man.

Books for Reference.

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General Characteristics of Vertebrates. — The body divided by a backbone into two cavities, — a dorsal containing the nerve centers, and a ventral containing the vital organs; sense organs paired; limbs never more than two pairs; skeleton internal.

Directions for Measuring and Preparing the Skins of Small Mammals.

Measuring. — The tools necessary for measuring are a pair of dividers, a good graduated rule, a flat board, and two stout pins. The measures should be taken before skinning.

Lay the animal upon its back on the board. Drive a pin, and bring the tip of the nose against it. Holding the head with one hand, straighten the body and tail by extending the hind legs. Drive a pin at the tip of the tail vertebræ. Measure the distance between the pins for the *length.*

Hold the tail at a right angle with the back, and with the dividers measure from the root of the tail to the tip of its last vertebra for the *length of the tail.*

Place one point of the dividers against the heel, and the other at the tip of the longest claw, stretching the foot for the purpose. This gives the *length of the foot.*

Skinning and Stuffing. — An animal should be skinned as soon after death as possible. The tools needed are scissors, scalpel, and spring forceps. Stout wire of annealed iron is necessary to support the tail, and should be of a size to fit easily into the tip. Before skinning remove blood stains by using a toothbrush and plaster of Paris or corn meal.

Then lay the animal on its back and make an incision through the skin along the middle line of the belly, cutting from the end of the sternum to the vent. With the scalpel loosen the skin from the body down to the legs. Skin down the leg as far as possible. Cut the leg at the knee or elbow joint, as the case may be. Cut across the rectum and pull out the tail, using the fingers. Cut any membranes which hold the skin to the body, and turn the skin back, using the fingers to push it loose. When the skin on the head is being turned, cut the membrane over the ear to free it. On reaching the eye, cut the membrane over it, but be careful not to cut the eyelids. Cut the membranes and muscles which hold the skin at the lips. It is then entirely free. Turn the skin and clean the leg bones by cutting the tendons just about wrist and ankle,

and stripping off the muscles. Reverse the skin again, and, after removing any fat or flesh that may adhere to it, dust the inside well with powdered arsenic. Wrap each leg bone with cotton, to make it about the size of the natural leg, and pull it down into its skin. Make a long roll of cotton the thickness of the body, leaving one end blunt, almost square. Take it near the blunt end with the forceps, and thrust it through the skin into the head, seeing that the head is well filled out. Take a piece of wire a little longer than the tail, and fit it into the tail, leaving the other end supported by the cotton. Remove the part of the roll not needed to fill out the body, and sew up the skin along the belly.

Lay the skin on the board, belly downward; extend the fore legs forward and parallel with the body; straighten the hind legs backward in the same manner; put the head and tail straight, so that the tip of the nose and tail are in a line with the median line of the body. Dry the skin in this position.

Clean the skull by removing the brains, tongue, and the flesh from the sides and base of the skull. Powder with borax, and put in a shady place to dry.

Attach to the skin a label giving the scientific name, sex, locality, and date of capture. Label the skull also. Skins made in this manner should never be roughly handled.

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